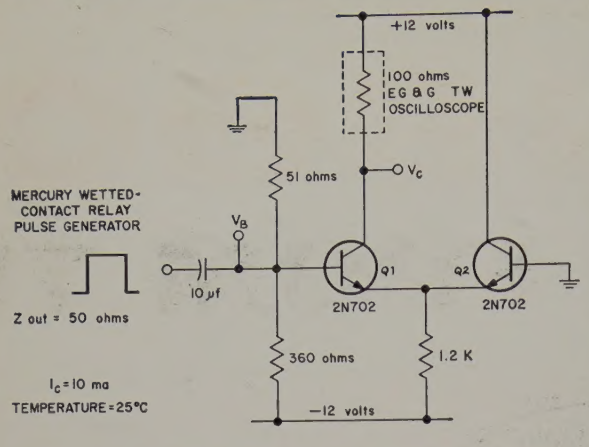
June 1959 75¢

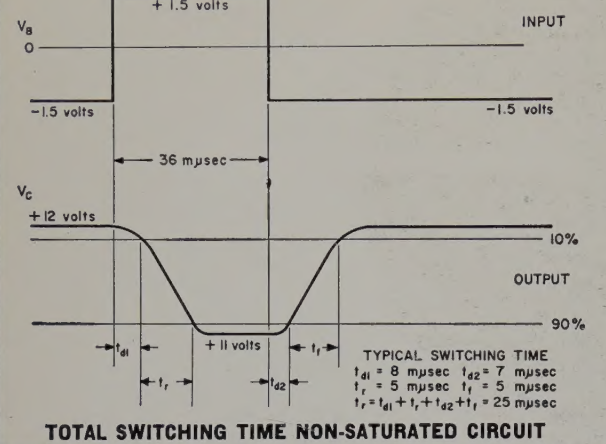
SEMICONDUCTOR PRODUCTS

IRE Show Review

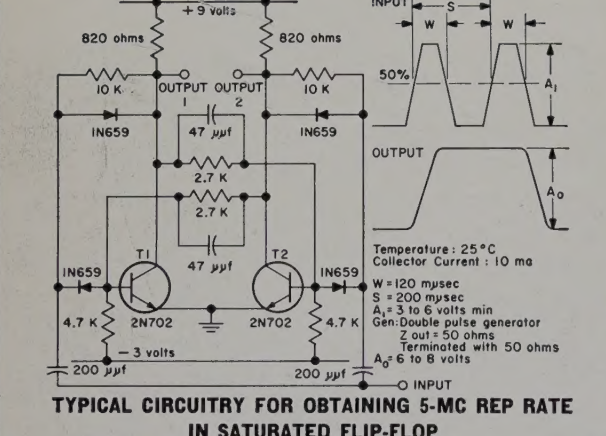
Stability Considerations in Transistor Feedback Amplifier Design • Vacuum Microbalance for Study of Semiconductor Materials • Static Characteristics of Transistors



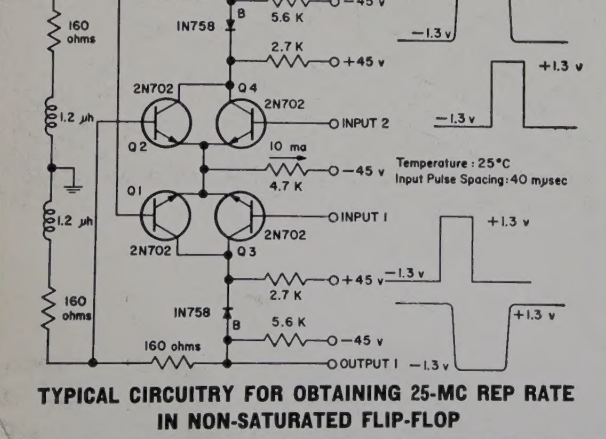
TYPICAL NON-SATURATED LOGIC SWITCHING CIRCUIT



TOTAL SWITCHING TIME NON-SATURATED CIRCUIT



TYPICAL CIRCUITRY FOR OBTAINING 5-MC REP RATE IN SATURATED FLIP-FLOP



TYPICAL CIRCUITRY FOR OBTAINING 25-MC REP RATE IN NON-SATURATED FLIP-FLOP

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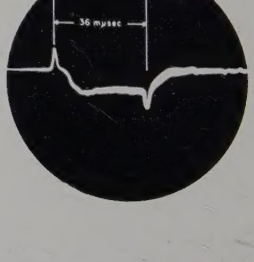
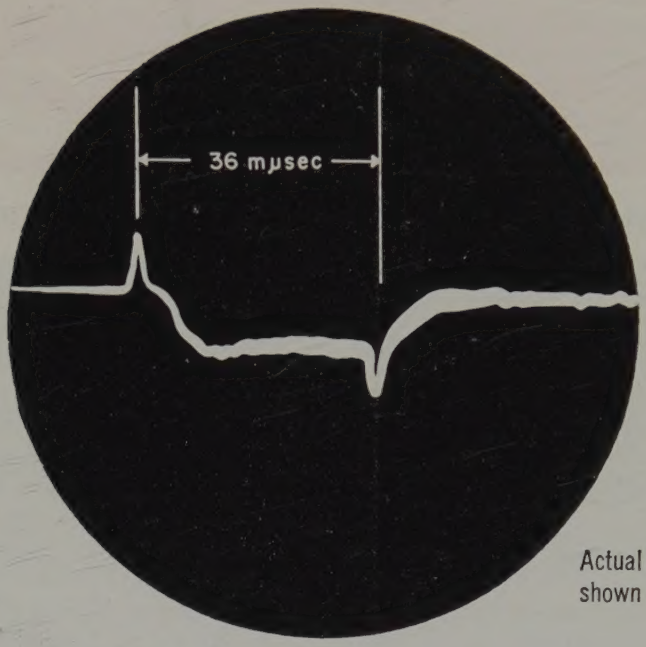


TEXA

FROM THE WORLD'S LARGEST SEMICONDUCTOR PL

25 mμsec SWITCHERS FROM TI



Actual photo of collector wave form as shown on traveling-wave oscilloscope

absolute maximum ratings (25°C)

Collector Voltage Referred to Base	20 v
Collector Voltage Referred to Emitter	15 v
Emitter Voltage Referred to Base	5 v
Collector Current	50 ma
Dissipation (100°C Free Air, Derate 0.5°C/mw)	150 mw

design characteristics at 25°C (except as indicated)

Symbol	Characteristic	Test Conditions	Min	Typ	Max	Unit
I_{CBO}	Collector Cutoff Current	$V_{CB} = 10$ v, $I_E = 0$			0.5	μa
I_{CBO}	@ 150°C	$V_{CB} = 10$ v, $I_E = 0$			50	μa
BV_{CBO}	Breakdown Voltage	$I_{CBO} = 10$ μa, $I_E = 0$	20			v
BV_{CEO}	Breakdown Voltage	$I_{CEO} = 10$ μa, $I_B = 0$	15			v
h_{FE}*	DC Beta	$V_{CE} = 5$ v, $I_C = 10$ ma	15		45	
BV_{EBO}	Breakdown Voltage	$I_E = 10$ μa, $I_C = 0$	5			v
V_{BE}*	Input Voltage	$V_{CE} = 5$ v, $I_C = 10$ ma	0.7		1.2	v
C_{ob}	Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, $f = 1$ mc		7	12	μμf
f_t	Frequency at which h_{fe} is unity	$V_{CE} = 5$ v, $I_E = 10$ ma	50	100		mc
V_{CE}* (Sat)	Saturation Voltage	$I_C = 10$ ma, $I_B = 2$ ma			0.6	v

* Tested using pulse measurement.

NOTE: These units meet JEDEC outline TO-18 dimensions. A drawing of this package is attached.

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Stud Type	Specification MIL-E-1/	Peak Operating Voltage −65°C to +135°C volts	Ave. Rectified Current 135°C Amps	Reverse Current (Max.) at 25°C μA at volts
JAN **1N253**	1024A	95	1.0	10 at 75
JAN **1N254**	989B	190	0.4	10 at 150
JAN **1N255**	990B	380	0.4	10 at 350
JAN **1N256**	991B	570	0.2	20 at 500

Wire in Type	Specification MIL-E-1/	Peak Operating Voltage −65°C to +165°C volts	Ave. Rectified Current 25°C mA	Ave. Rectified Current 150°C mA	Reverse Current (Max.) at 25°C μA at volts
JAN **1N538**	1084A	200	750	250	10 at 200
JAN **1N540**	1085A	400	750	250	10 at 400
JAN **1N547**	1083A	600	750	250	10 at 600

RAYTHEON PNP GERMANIUM TRANSISTORS

Type	Service	Specification MIL-T-19500/	V_{CE} max. volts	H_{FE}† ave.	$f_{\alpha b}$ min. MC
USAF **2N404**	Computer	20 (USAF)	−24*	30	4.0
U. S. Army **2N425**	Computer	41A (Sig. C.)	−30*	30	2.5
U. S. Army **2N426**	Computer	42A (Sig. C.)	−25*	40	3.0
U. S. Army **2N427**	Computer	43A (Sig. C.)	−20*	55	5.0
U. S. Army **2N428**	Computer	44A (Sig. C.)	−15*	80	10.0
				h_{fe}‡ ave.	
U. S. Army **2N416**	R.F., G.P.	56A (Sig. C.)	−12	60	5.0
U. S. Army **2N417**	R.F., G.P.	57A (Sig. C.)	−12	80	15.0
U. S. Army **2N464**	Audio, G.P.	49B (Sig. C.)	−40	22	0.4
U. S. Army **2N465**	Audio, G.P.	50A (Sig. C.)	−40	45	0.5
U. S. Army **2N466**	Audio, G.P.	51A (Sig. C.)	−35	90	0.5
U. S. Army **2N467**	Audio, G.P.	52B (Sig. C.)	−35	180	0.6

*Min. Punch Through Voltage †I_B = 1mA, V_{CE} = 0.25V ‡I_E = 1mA, V_{CB} = 6V, f = 1000 cps.

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Front Cover

Diffused-base transistors are providing industry with new highs in device performance, mechanical ruggedness and reliability. At Texas Instruments, this kind of advanced uniformity is obtained by processing many transistors in each production step. A Texas Instruments specialist is shown inserting germanium wafers into a diffusion furnace where base layers will be diffused into more than 26,000 transistor elements. Next, microscopic gold contact strips are applied by high vacuum evaporation. 40 transistors are shown in the circular photo magnified more than 33 times. Not until just before mounting on the header are the active transistor elements separated.

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1N276	40	100 @ −50V 100 @ −10V*	60
1N277	100	250 @ −50V* 75 @ −10V*	125

*Measured @ 75° C.

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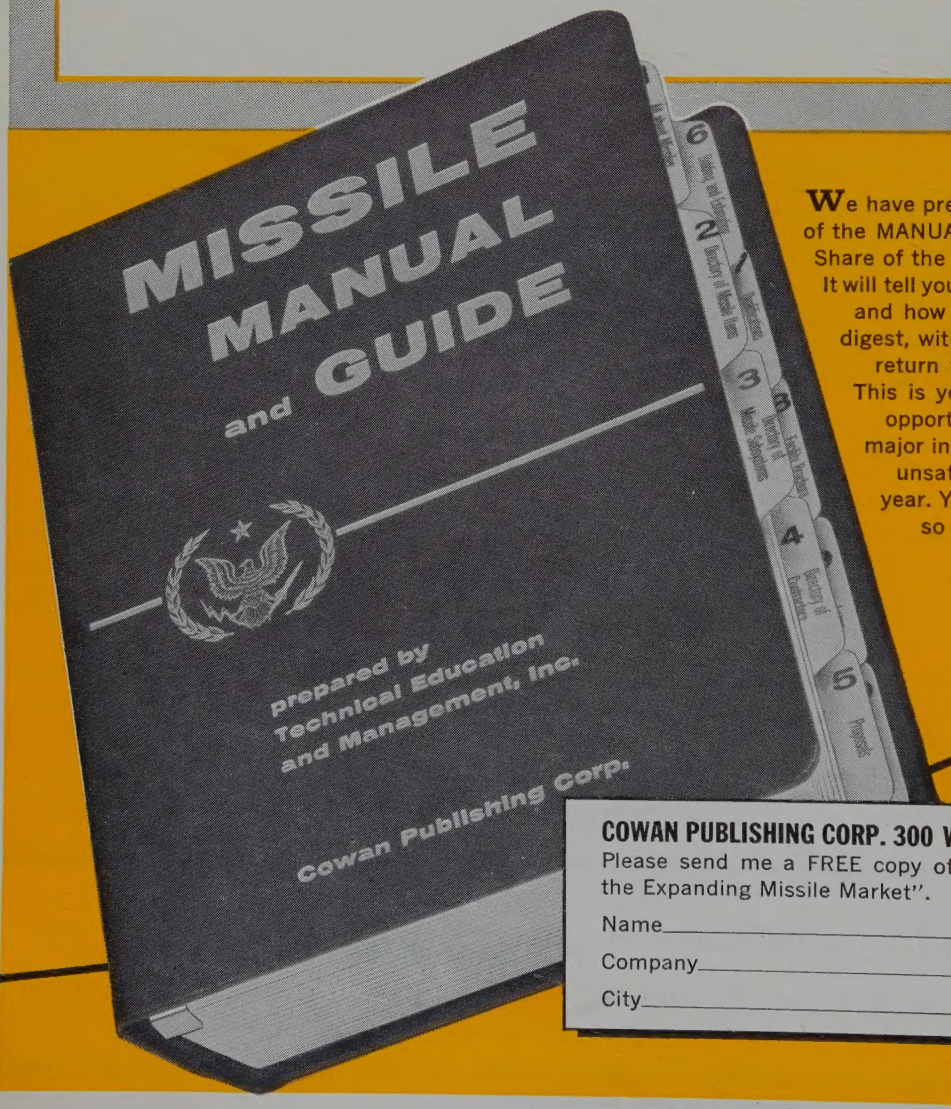

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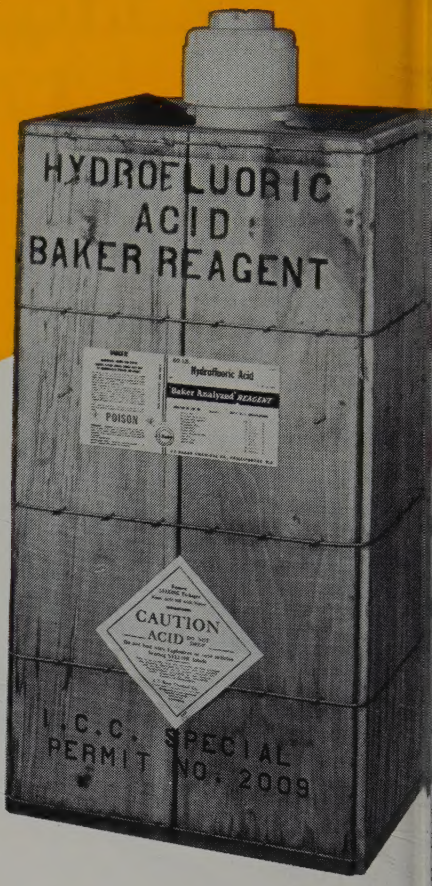

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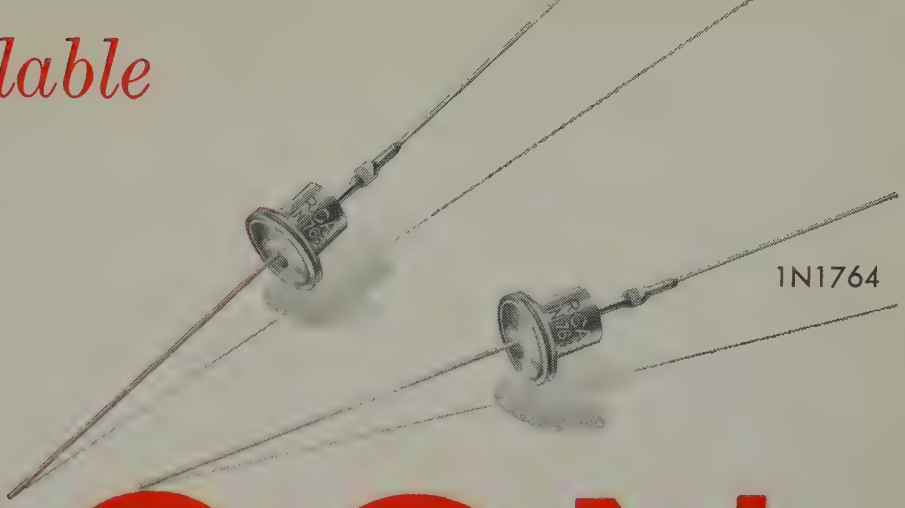

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TYPE	MAXIMUM RATINGS			* CHARACTERISTICS		APPLICATION
	Peak Inverse Volts	RMS Supply Volts	DC Forward Ma	Max. Reverse Current at Indicated Peak Inverse Volts	Max. Instantaneous Forward Voltage at Indicated Instantaneous Forward Current	
1N1763	400	140	500	100 μa at 400 volts	3 volts at 15 amperes	Black-and-white TV, radios, phonographs and other electronic equipment operating direct from power line
1N1764	500	175	500	100 μa at 500 volts	3 volts at 15 amperes	Color TV, radios, phonographs and other electronic equipment operating from the power line through a step-up transformer

*At ambient temperature of 25°C

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1959 IRE SHOW REVIEW

OF NEW PRODUCTS

The items described in this section are those which the respective manufacturers considered of major interest in their exhibits.

Switching Transistor Pack

Introduced by Sylvania, this Pack contains 18 NPN Switching Transistors comprising 3 each of the six most popular types, 2N356, 2N357, 2N358, 2N377, 2N385 and 2N388. 2N356-7-8 have 100 mw dissipation and 2N377, 385 and 388 have 150 mw dissipation. Base is internally connected to case for internal dissipation. Each type welded hermetically sealed. Meets JEDEC TO-5 and TO-9 specifications. For all industrial applications, computers, electronic controls, etc. Package also contains 8-page booklet giving complete specs and data on each type. Available to equipment customers through local authorized distributors.

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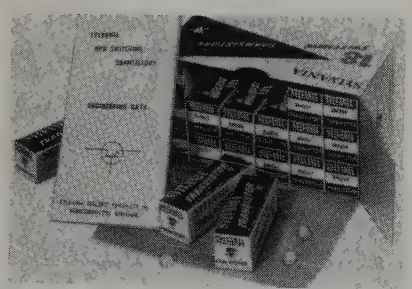

Temperature-Altitude Test Units

An important advance in the type of combined environmental test facilities required in the design and construction of parts and components for today's aircraft and missiles is the Tenney Engineering VT-10 unit. This is one of a new line of combined temperature-vibration and temperature-altitude test units available in three sizes—the Tenneymite for small component testing, the VT-10 (10 cubic feet) and the VT-27. Shown is the removable hatch in the bottom of the chamber—a silicone-coated diaphragm through which a component can be mounted for vibration testing in relation to temperature changes ranging from minus 100°F to plus 500°F. For temperature testing, without vibration, the screen is replaced by a solid hatch. For easy use with a vibration unit, new chambers are supplied with fork lift truck mounting.

Circle 131 on Reader Service Card

Subminiature Selenium Diodes

MINIFIERS — subminiature selenium diodes, designed specifically for high reliability and long operating life in applications such as detectors, gating, logic circuitry, phase comparators, bias supplies, clamping, clipping, AFC, AGC, and sensitive DC relays. Featured by International Resistance Co. Assembled in a drawn brass housing to provide high-efficiency heat dissipation and better mechanical protection, and then coated with a thermosetting material for environmental protection. The complete assembly is only 3/32" in diameter and fully insulated to permit its use where space is limited. Munifiers have a useful life expectancy greater than 20,000 hours when operated within ratings.

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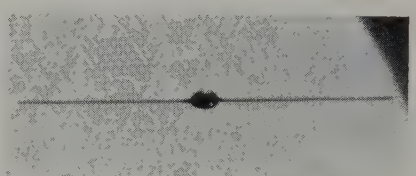

Silicon-Filament Power Supply

Two d-c power supplies in one, this rugged, compact unit provides two continuously adjustable d-c power outputs, 6 to 10 volts, 50 amperes, and 6 to 10 volts, 10 amperes. Power from each output can be drawn separately or simultaneously. Manufacturer claims voltage regulation of ±0.5%, ripple of 60 millivolts maximum peak to peak, and recovery time of 0.2 second. Designated type D-10-10-100KS4, unit was designed by Christie Electric Corp., and has hermetically sealed silicon diode rectifier elements.

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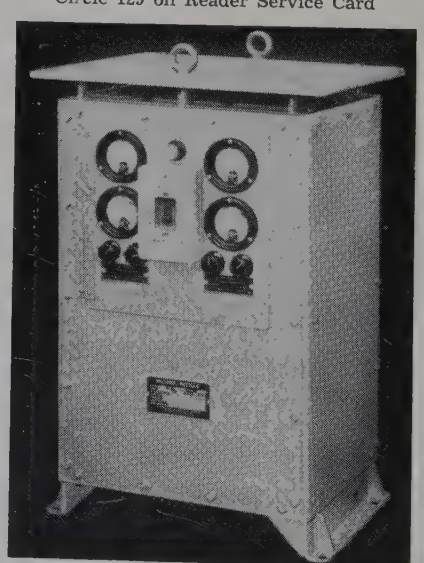

Transistorized Tape Recorder

Electronic Applications, Inc., model 111 B NAGRA transistorized professional tape recorder. This unit meets primary recording standards. 30 transistors are used in the motor and electronic assembly. A DC motor is driven at high stability and a servo loop control system monitored by power transistors and data from tachometer head. (Speed constancy 0.1%). Signal to noise is better than 60 db. Unit weighs 15 lbs. Measured noise at input to microphone pre-amplifier is —112 dbm.

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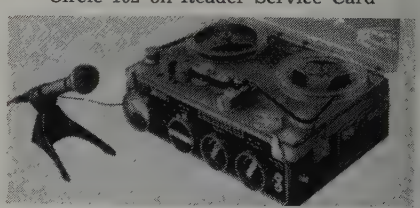

Miniature Quartz Sealcaps

JFD precision Miniature Quartz Sealcaps seal out moisture, seal in reliability and accuracy, regardless of atmosphere. Variable trimmer piston capacitors combine characteristics of Sealcap construction and miniature quartz capacitor design. Each is filled with dry nitrogen under pressure and then sealed to maintain the compression, prevent corona and voltage breakdown at high altitude. Linear tuning with fine resolution is assured without breaking of seal. Available unpotted or encapsulated in epoxy resin for higher dielectric strength.

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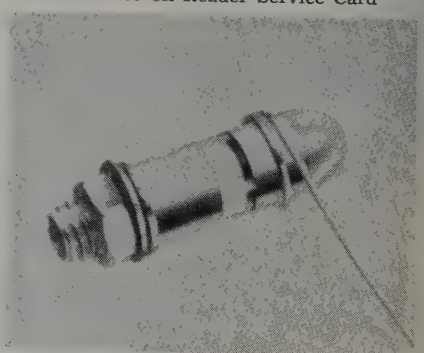

Metal Products

Pure metals and alloys such as Antimony-Gold, Gallium-Gold and Chemically Pure Gold; minimum purity 99.99%. These materials are available in fine wire form to approximately .001" or smaller; sheet form to approximately .0005". Manufactured by Sigmund Cohn Corp. Continuously electroplated base metal wires can be supplied coated with material such as Indium-Gold or Antimony-Gold.

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(*continued on page 12*)

crystal growing with Trancoa silicon . . .

single, single all the way

POLYCRYSTALLINE SILICON SPECIFICATIONS

Grade	Resistivity P-Type	Resistivity N-Type	Max. Resistivity Ratio for 10% & 60% Points	Max. Boron Content (ppb)
IA	500	250	3:1	0.5
I	100	50	3:1	0.5
II	50	20	3:1	1.0
III	25	10	3:1	2.0
IV	2.5	1.0	3:1	4.0

Consistently clean Trancoa Silicon eliminates the twins, polys, and dropped charges that can result from dirty material. This will give you a larger yield of single crystal per pound of silicon . . . saving material, saving machine time, saving labor.

We prove the cleanliness of our Silicon at Trancoa by growing test crystals with only 3/16th of an inch between crucible and crystal . . . and they are single, single all the way! You can be confident of achieving uniform results within a lot and from one lot to another by growing crystals with Trancoa Silicon.

See table for the five grades available. Complete information is contained in "Trancoa Methods for Evaluating Silicon". Write today for a copy.

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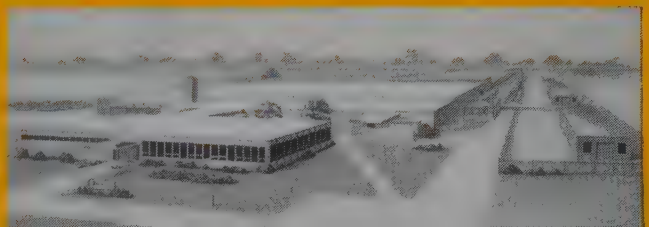

How to increase your semiconductor yield ...with ALPHA UHP ultra high purity dot materials

Uniformity—in alloy composition and dot purity level—is significant in increasing alloy junction semiconductor yield.

To insure uniformity, all ALPHA dot materials—pellets, discs, washers, spheres and other forms—are produced by the "basic melt principle" as follows:

1. **Using metals** as refined as 99.999%+ purity, ALPHA carefully prepares the alloy in special, non-metallic vessels. (ALPHA offers all standard alloy combinations, fabricates special ones to your requirements.)
2. **ALPHA then analyzes** the alloy for major and minor constituents. Spectrographic analysis provides a further check on impurities.
3. **Found within specifications,** the melt is next fabricated on equipment used exclusively for ALPHA UHP* ultra high purity metals. The entire batch is processed at *one* time; equipment is specially allocated for each alloy combination; this safeguards against contamination, insures finished dot uniformity.
4. **As with the original batch,** the finished dots, too, are spectrographed for purity.
5. **Next, each finished lot** is rigidly inspected for conformity to dimensional and weight requirements. Measurements are made with the most precise balances and high-precision gauges.
6. **Lastly, all ALPHA UHP** dot materials are packed in protective, sealed containers.

The result of these rigid controls is ALPHA UHP ultra high purity dot materials. Their uniformity and correct constitution are important in controlling penetration and producing uniform junctions. *You gain increased semiconductor yield!*

FREE! For informative technical data, write today!

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IRE Review

(*from page 10*)

Silicon Rectifier

Type T silicon rectifier, representing a major break-through in semiconductor devices, gives radio and television designers a commercial unit with high quality and reliability. Developed by P. R. Mallory & Co., Inc., it has a diffused junction and is designed for 85°C ambient temperature. Has low reverse leakage current and low forward voltage drop. Encapsulated in a coating compound called "Mallo-Seal", it has high stability under severe moisture and humidity conditions.

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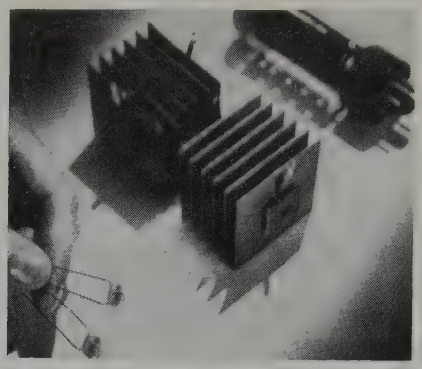

NPN Silicon Power Transistors

Exhibited by Silicon Transistor Corp., 30 watt, 5 amp., low saturation resistance. Jedec outline TO-3 in a welded hermetically sealed package. Operating temperatures: from −65° C. to 175° C. Typical applications: Class A and B power amplifiers, power converters, relay replacement and controls, power switches, high level DC amplifiers and power supply regulators.

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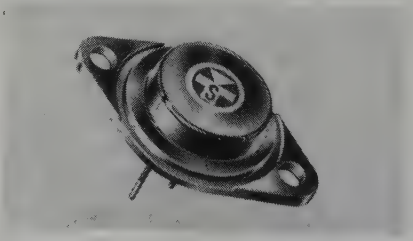

High Speed Switching Transistors

Fairchild 2N1131 and 2N1132 are PNP silicon transistors closely matching 2N696 and 2N697 types. Existence of these closely related devices of opposite polarity affords opportunities for circuit designs based on complementary symmetry. Typical rise time is 80 milli-micro-seconds. Dissipation ratings are 2 watts at 25°C. and 1 watt at 100°C. Stabilized by 300°C storage. Mesa structure minimize effects of thermal and mechanical shocks.

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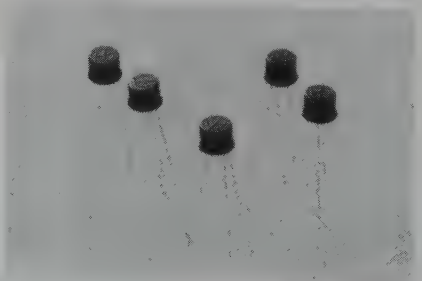

Solder Microforms

Anchor Metal Co., displayed stock and specification samples of solder microfilms made from ultra-high purity and Grade A metals and alloys. Some of the variety of shapes included: Rings, pellets, drops, segments, foil, powder, balls, etc. Including among the metals and alloys were: indium, indium-gallium, indium-gold, indium-tin, indium-lead, gold-antimony, gold-gallium, tin, tin-antimony, tin-lead, tin-arsenic, lead-antimony, lead-arsenic, aluminum, aluminum-tin, platinum. Some advantages for semiconductor applications are: No waste, faster flowing, higher production, saves solder.

Circle 115 on Reader Service Card

Germanium PNP High Power Transistors

Clevite 2N1146 and 2N1147 series features ring emitter construction and large junction area for conservative current and power ratings. Low thermal resistance, low base input voltage, low saturation voltage, and superior current gain up to high values of collector current make them ideal for use in high current switching circuits, DC to DC converters, high power audio amplifiers and voltage regulated power supplies. New voltage and current rating curve allows design for operation in regions safe from damage due to hot spots caused by high local current densities. Highest reliability of operation is insured by exacting standards throughout processing and by rugged mechanical design featuring a new projection weld technique.

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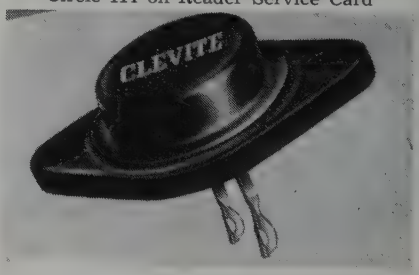

Switching Transistor Line

A comprehensive line of NPN transistors for high-speed switching and high-frequency amplification has been introduced by CBS-Hyton. The line comprises 10 computer types suited for logic-circuit and core-driver applications. These alloy-junction germanium transistors feature high current and voltage, flat gain, and low saturation resistance. They use a reliable, welded JEDEC TO-9 package. Typical operating frequencies range from 3 to 12 megacycles, with maximum dissipations of 100 and 150 milliwatts.

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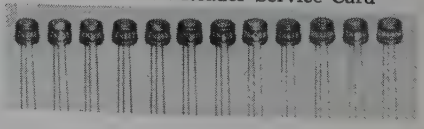

High Power Silicon Rectifier Series

Audio Devices displayed their line of Power Silicon Rectifiers. Electrical Characteristics (Resistive Load): DC Load; 25A-200 Amp (nominal average current in half-wave circuit), Plus: 59 to 400, Max. Operating Temp: Up to junction temp of 190° C., Max. Reverse current at rated PIV, 25A unit: 25 ma, 200A unit: 100 ma, Instantaneous forward drop at rated DC load current and 25° C junction temp: 1.5 volts max. Available with "Positive" or "Negative" Base Hermetically sealed, High Efficiency, Rugged Construction.

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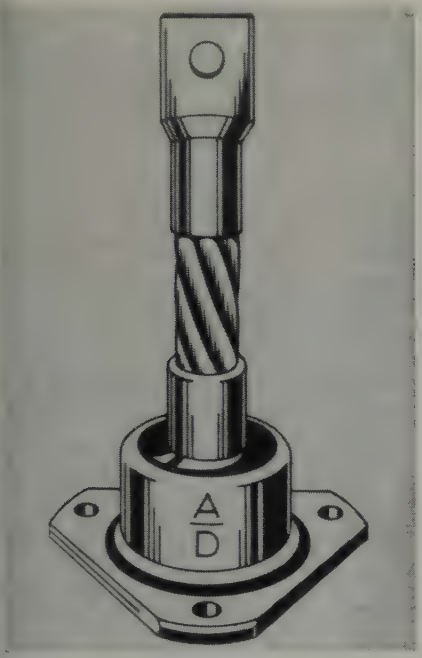

Data Strip & Data Matrix

Dialight Corp., Dialco Data Strip designed to provide a number of ultra-miniature indicator lights, as a unit, ready for mounting in a minimum of space. The basic indicator light consists of a lampholder with a plug-in lamp cartridge. Lamps used are T-1-¾ Incandescent Lamp from 1.35 to 28 V.; or NE-2E Neon Lamp for 105 to 125 V. circuits. Holds 10 lamp holders, but Data Strip can be made with any desired number of lampholders on the aluminum channel, for vertical or horizontal reading. The Data Matrix is similar to the Data Strip but rectangular in shape.

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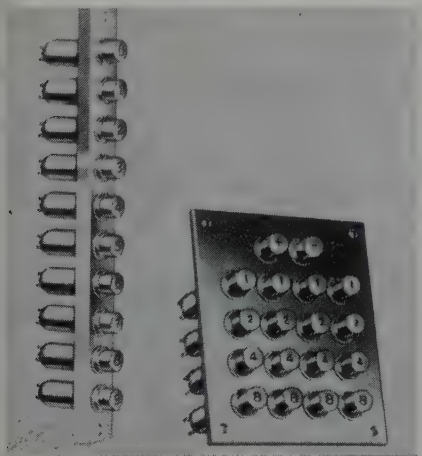

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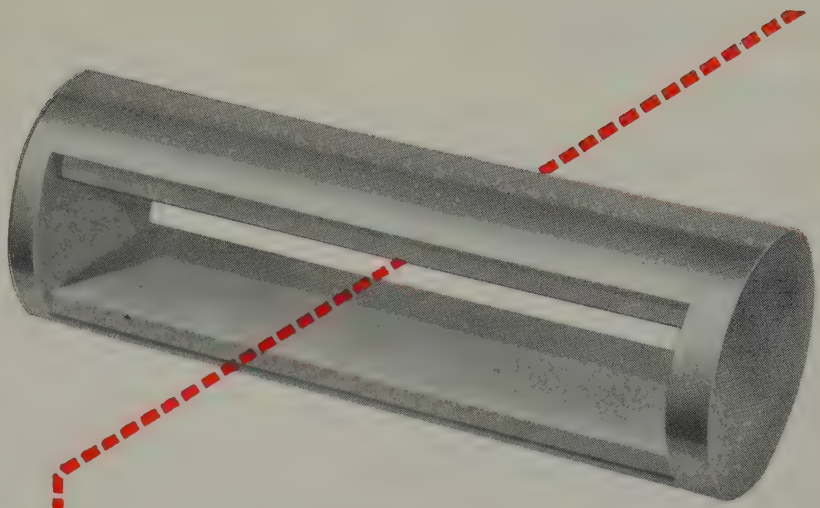

What Does a Slide Pin Have to Do With the Cost of VACUUM?

A rotary piston mechanical pump *must* have a slide pin! And, there's a dramatic difference in the cost picture between a precision-built, one-piece KINNEY slide pin and one that doesn't possess the same engineering niceties. The performance record of KINNEY High Vacuum Pumps in production service accents the big savings in wear, maintenance and downtime of KINNEY one-piece slide pin design. Anything less than superior engineering, quality materials and true craftsmanship just does not belong in a critical part of a Vacuum Pump. You do not risk this gamble when you buy

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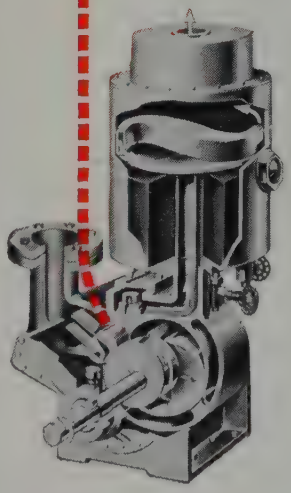

HIGH VACUUM PUMPS

KINNEY—the top name in High Vacuum—offers the broadest selection of Single-Stage, Two-Stage and Mechanical Booster Pumps in the world with free air displacements from 2 to 5100 cfm. Single-Stage Pumps developing pressures of 10 microns*... Compound Pumps developing pressures of 0.2 micron* and Two-Stage Mechanical Booster Pumps developing pressures to 0.1 micron*.

*McLeod Gage

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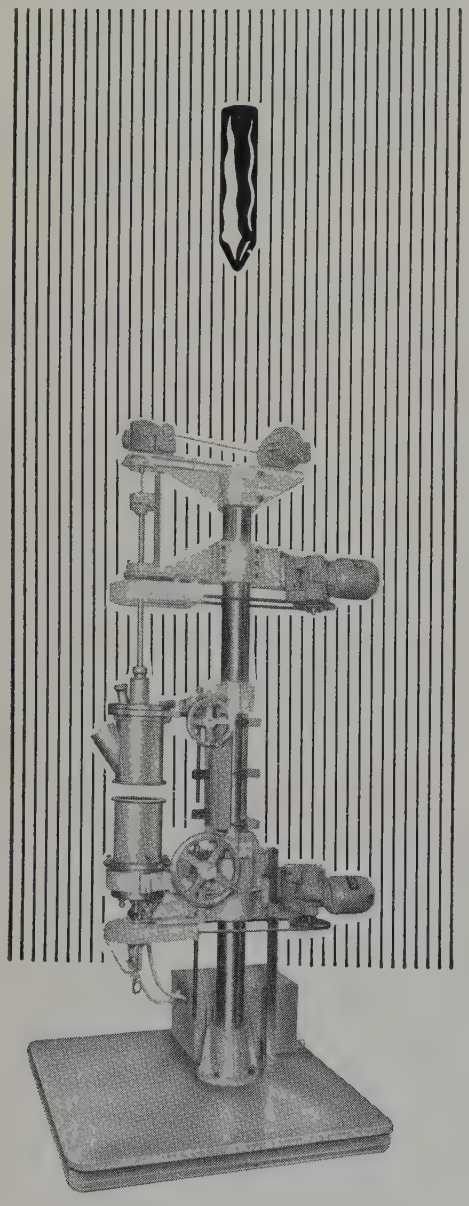
THE BEST SEMI-CONDUCTORS MADE....



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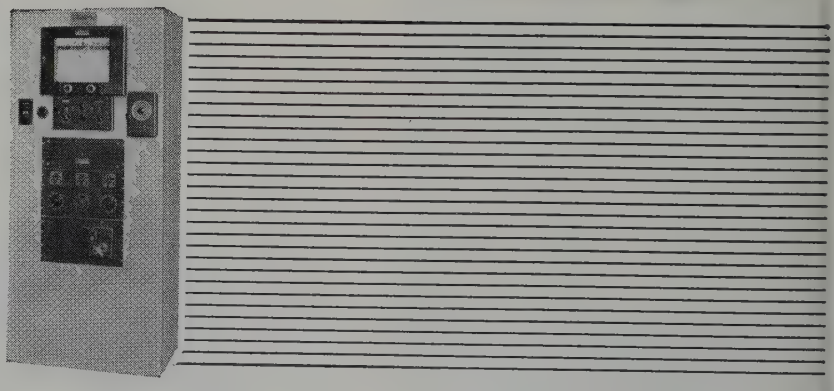

KAHLE CRYSTAL GROWING MACHINES . . . featuring a single unit for temperature, timing, programming, and motor control...set new high-precision standards in the production of single billets of Germanium, Silicon, or related semiconductor crystals. Designed to function efficiently and economically with either RF or resistance-type heating systems, each machine is pre-tested . . . under actual operating conditions . . . prior to shipment.

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Editorial . . .

Avalanche Breakdown Phenomena in P-N Junctions

The phenomena of avalanche breakdown in reverse biased semiconductor diodes are generally accompanied by secondary effects of instability. The effects appear as a region of negative slope in the voltage-current characteristic. They were first observed in point contact diodes and later noticed in germanium alloyed junction diodes, and have been investigated by various scientists in an attempt to explain their occurrence to reduce them to a theoretical evaluation. From a technical point of view they are of considerable importance for possible applications in the generation and amplification of very high frequencies, and in the design of avalanche diodes for given breakdown voltage.

The resulting breakdown voltage is generally lower than the value computed theoretically from the avalanche theory. Furthermore, since the negative resistance characteristic is of the open circuit stable type, operation with low source supplies produces runaway and corresponding fusing of the diode. The negative resistance characteristics can be obtained experimentally if sufficient external resistance is introduced in series with the breakdown diode. It is observed that switching phenomena in the instability region take place in times of the order of 10^{-9} sec.

An interesting theory was advanced recently by A. W. Matz (Proc. I.E.E., Part B, p. 555) in which it is supposed that the negative slope is due to thermal runaway combined with the avalanche multiplication characteristic

$$I = -I_s/\left(1 - \left(\frac{V}{V_B}\right)^n\right).$$

In fact, assuming that thermal equilibrium is obtained between heat internally produced, $P = VI$, and heat externally dissipated, $S(T - T_a)$, where T_a is the ambient temperature, a resulting expression of the static conductance may be derived which becomes negative when the current I increases beyond a certain value. The "turnover" voltage V_{max} may be expressed in terms of the excess temperature of the semiconductor at breakdown $T_1 - T_a$, which is typically about 14° C for germanium, with the equation

$$V_{max} = \frac{T_1 - T_a}{SM_i I_s}$$

In this equation S is typically ~ 0.35 C°/mw for germanium and $M_i\ I_s$ is the avalanche diode current at the turnover point.

Transistorized Power For Buses

Announcement by G.E. of an experimental transistorized fluorescent lighting system installed in one of the buses of the Cleveland Transit System marks a promising application of semiconductor devices in transportation. The heart of the system is a transistor inverter which converts 12-volt d-c battery power to 3000 cycle, 400-volt a.c. It supplies each fluorescent lamp at 20 watts through special ballasts which are five times smaller and ten times lighter than the conventional ballasts used with these lamps on standard 60-cycle power sources. The ballast watt losses are reduced from 21 to 2, thereby increasing system operating efficiency considerably. The system produces three to nine times the illumination of former filament bus lighting, and consumes only three-quarters the wattage.

Transistorized Artificial Larynx

A new artificial larynx for persons who have lost their voices through surgical removal or paralysis of their vocal cords was described recently by Bell Telephone Laboratory scientists. By means of a finger-operated combination push-to-talk switch and inflection control, the user can easily control the pitch of his artificial voice. The underlying principle of the device is a vibrating driver held against the throat. Included in a package 1¾ inches in diameter by 3¼ inches long is a modified telephone receiver serving as a throat vibrator, a transistorized pulse generator with pitch control, and a battery power supply consisting of two 5.2-volt mercury cells.

This new application of semiconductor devices in the field of medicine is indicative of the good that can be done with devices of this type. No greater satisfaction can be enjoyed by man than the feeling that he has contributed to the welfare and relief of his fellow man.

Samuel L. Marshall

Transistor Engineer Wanted, To Head Laboratory, Italy

olivetti

Olivetti (Italy) has established a subsidiary in Milan for the production of silicon and germanium transistors and diodes.
It is now looking for the right person to head the existing development laboratory.
These are the requirements: (1) At least 5 years experience in transistor development
(2) Degree of Master of Science in Physics
(3) Willingness to move to Italy and learn Italian.
It would be desirable if you were familiar with present applications and future potentialities of transistors and diodes, in order to contribute actively to the general policy of the new firm.
Salary will be commensurate with experience and ability. Transportation and moving expenses will be paid.
Written replies will be sent to all applicants.
Chosen candidates will be invited for a personal interview in New York City, expenses paid.
Please write, enclosing detailed resume, to Project
T. D. L., Olivetti, Ivrea, Italy.

Electronics progress through chemistry and metallurgy

New look in Crystals...

Sylvania develops a new optical instrument for easy, accurate alignment of single-crystal germanium and silicon

Semiconductor manufacturers and research laboratories can now orient monocrystalline germanium and silicon quickly and easily without the use of X ray, microscope or other methods requiring skilled operators or extensive processing.

Sylvania has developed a versatile new Crystal Orientation Instrument that is especially adaptable to the preparation of germanium and silicon single-crystal slabs for dicing, to seed crystal preparation, and many other uses. The device reveals the symmetry and orientation of a crystal through the light pattern it reflects from the facets in the etched surface of the crystal.

Here are some of the advantages of the Sylvania Crystal Orientation Instrument:

SPEED—Cutting, preparation, etching and evaluation of a crystal in as little as 15 minutes.

SIMPLICITY—Clean design allows easy operation by unskilled personnel.

ACCURACY—to ± 12 minutes of arc.

ECONOMY—Lower initial and operational costs than X ray and other techniques.

SAFETY—Non-hazardous operation—no radiation risk.

VERSATILITY—Can be used on any monocrystalline material in which etch pits can be produced.

FLEXIBILITY—Top mount can be rotated or removed. It can be set up on duplicate base units in other locations.

The Sylvania Crystal Orientation Instrument is available as a complete assembly or in individual parts. For complete particulars on this newest aid to the semiconductor industry from the Chemical & Metallurgical Division, contact your Sylvania representative or write the division directly in Towanda, Pa.

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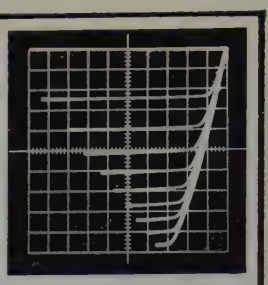
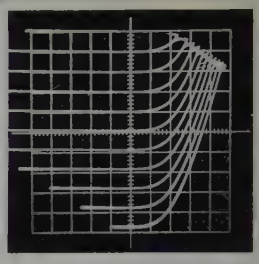


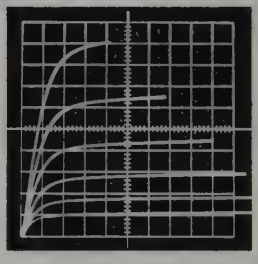
HIGH COLLECTOR CURRENT

PNP transistor, collector current vs collector voltage with constant-current base steps. Collector sweep is 0 to 5 v with a 0.25-ohm load, base current is 50 ma/step. Vertical deflection is 1000 ma/div, horizontal 0.5 v/div.



HIGH INPUT CURRENT

PNP transistor, collector current vs collector voltage with base grounded and constant-current emitter steps. Collector sweep is 0 to 1.5 v, emitter current 200 ma/step. Vertical deflection is 200 ma/div, horizontal 0.1 v/div. Zero voltage is at center scale.



LOW INPUT CURRENT

NPN transistor, collector current vs collector voltage with constant-current base steps. Collector sweep is 0 to 1.5 v, base current 1 microamp/step. Vertical deflection is 10 microamp/div, horizontal 0.1 v/div.

Transistor-Curve Tracer

TYPE 575 CHARACTERISTICS

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Horizontal axis—
Collector volts, 11 steps from 0.01 v/div to 20 v/div.
Both axes—
Base volts, 6 steps from 0.01 v/div to 0.5 v/div.
Base current, 17 steps from 0.001 ma/div to 200 ma/div.
Base source volts, 5 steps from 0.01 v/div to 0.2 v/div.

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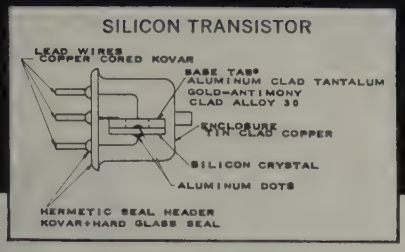
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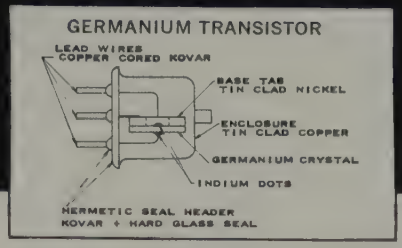
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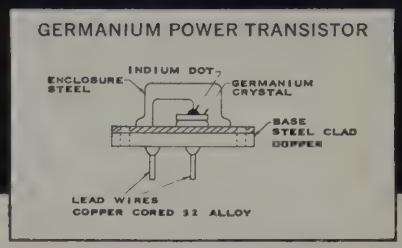

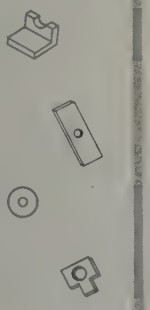

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5. 63.2% Lead-35% Tin-1.8% Indium Clad Nickel
6. 63.2% Lead-35% Tin-1.8% Indium Clad Alloy 30
7. 99% Tin-1% Gallium Clad Nickel
8. 98% Tin-2% Antimony Clad Nickel
9. 95% Tin-5% Antimony Clad Nickel
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11. Tin Stripe on Nickel
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3. 99% Gold-1% Gallium
4. 95% Gold-5% Indium
5. 99.9% Gold-.1% Boron
6. 99% Gold-1% Aluminum
7. 99% Gold-1% Arsenic
8. Fine Silver
9. 99.5% Silver-.5% Antimony
10. 95% Silver-5% Indium
11. Aluminum
12. High Purity Aluminum

BASE METAL

1. Nickel
2. Alloy 20 (40% Nickel-60% Iron)
3. Alloy 30 (42% Nickel-58% Iron)
4. Kovar
5. Titanium
6. Tantalum
7. Molybdenum
8. Silver
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4. 90% Platinum-10% Iridium

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3. Nickel Clad Steel (Nifer)®
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IRE Review

(from page 13)

Ultra Fast Transistor

TI's new NPN silicon diffused-base mesa transistor is designed and characterized especially for high speed switching applications. Packaged in a sub-miniature TO-18 package with the E3-58 base, the 2N702 features a typical total switching time of 25 mu secs in a typical logic non-saturated switching circuit. Other device highlights include the following absolute maximum characteristics at 25° C: 20V minimum collector voltage referred to base, 15V minimum collector voltage referred to emitter, 5V minimum emitter voltage referred to base, and 50 ma collector current. Device operating temperatures extend from —65° to +175°C.

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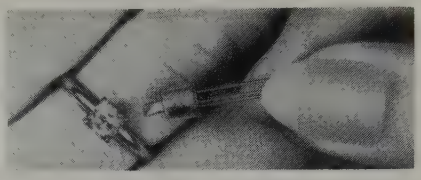

Crystal Orienting System

A system for orienting silicon and germanium crystals by visual patterns, eliminating measurement of degree of mis-orientation and transfer of data, introduced by Micromech Manufacturing Corp. Immediate, accurate identification of principal planes is made from undistorted patterns reflected from the etched crystal surface. The aligned crystal mounted on the orientation fixture is transferred from the orientation base to the table of the wafering machine, allowing the crystal to be cut on the plane to which it was aligned.

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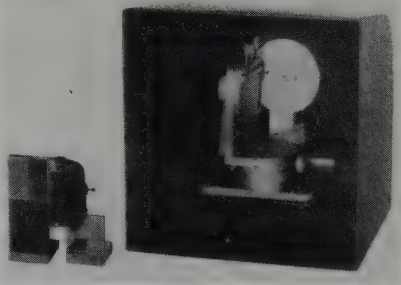

Spike Elimination

Universal Transistor Products Transistorized Power Supplies for communications and navigation applications provide built-in protection against the spikes and transients disturbing system voltages in air-ground systems as described in MIL-E-7894A. Model 6073 is 6¼" x 3½" diameter; weighs 2 lbs. 12 ozs. Produces 300V and 100V from 27VDC input. Operates in temperatures from —40°C to +80°C.

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Vacuum System

The Kinney Ultra High Vacuum System is the first standard working equipment producing pressures in the order of 10^{-9} mm Hg. with practical time cycles. Utilizing the principle of differential pumping, the outer chamber is pumped down to 10^{-4} to 10^{-5} mm Hg. and the inner chamber is differentially pumped down to the ultimate pressure. The System is equipped with electric feed-throughs, rotary motions, and other fittings customarily associated with Vacuum Evaporation.

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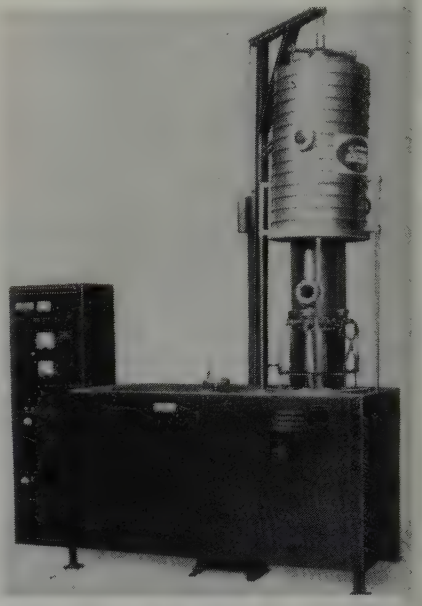

Medium Power Transistor

The Delco 2N1172 is a medium power PNP germanium transistor designed for use with a 12 volt power supply. It is particularly applicable for use where size is an important consideration. It is characterized by a maximum emitter current of 1.5 amperes, a maximum collector diode voltage of 40 volts, and a maximum thermal resistance of 15°C/watt. Due to its high gain and low saturation resistance, the 2N1172 will give good performance in audio and power regulating applications. It will deliver 400 milliwatts of power when operated in single-ended class A service. It may be efficiently used to drive a loudspeaker directly or to furnish drive for subsequent power amplifier stages. The collector is electrically connected to the case of the transistor.

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Ultrasonic Liquid Level Switch

Acoustica Associates, has developed a miniature, glass-aluminum sensing element for use with low boiling point fluids. This sensor is designed for use with an external miniaturized control unit which, in combination, form a liquid level switching system. Units are small, lightweight, hermetically sealed, and operate over a wide range of stock, vibration, temperature and altitude. Response time is 25 milliseconds max. Functions well in cryogenic and most other fluids up to 160° F.

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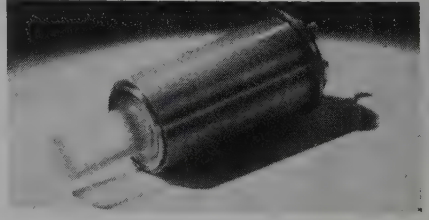

Automatic Transistor Production

Philco exhibited an almost completely automated mechanism, capable of producing 450 transistors an hour. The machine is called the "F.A.T." line (for Fast Automatic Transfer.) It was designed to answer the entertainment industry's need for quality transitors at lower cost. 18 workers can assemble and test about 1,000,000 transistors a year. Two units of the machine are completely automated, requiring no manuel labor, and these two combined account for 33 operations required in the production of transistors. About the only thing the machine does not do is plate, test, brand and pack the finished transistors.

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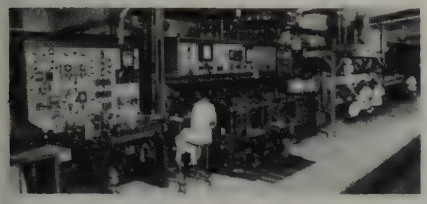

Silicon Trinistor

The Westinghouse Trinistor is a three terminal multi-junction silicon NPNP switch, whose breakover voltage can be controlled by the base current. In the forward or conducting direction, with no input signal to the base terminal, the device will block up to the full rated voltage. When a base signal is applied, the Trinistor will switch from a blocking to a conducting condition, characterized by a low forward drop similar to that of a conventional silicon diode. Ideally suited to applications in circuits with voltage up to 400 volts and currents up to 50 amperes.

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Trigger Switch Housing

Trigger switch incorporating the General Electric NE-177 Special Purpose Glow Lamp marketed by Drake Manufacturing Company. The switch, No. X3245, is of 1-piece body-and-dome polystyrene construction. Its design makes soldering lugs readily accessible. The GE lamp has a three-electrode structure, requires no heater current, and will operate many thousand times. While some glow is produced, the lamp is not intended as an indicator.

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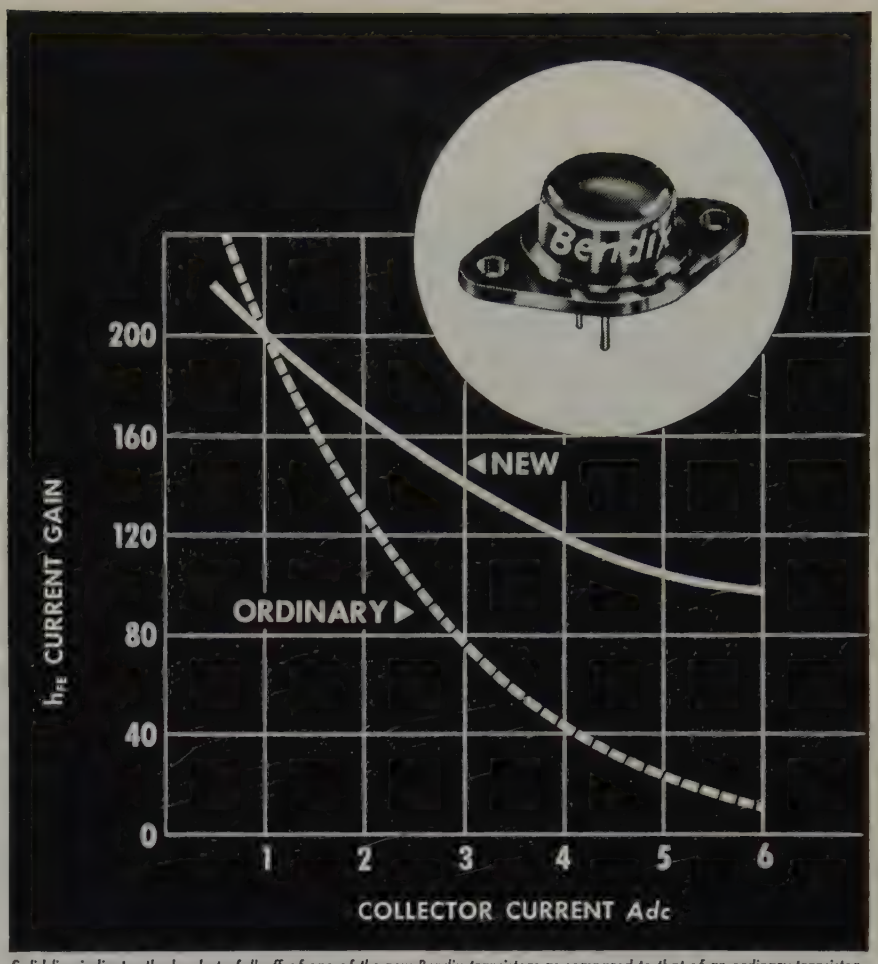
(continued on page 58)



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Some Stability Considerations in the Design of Large Feedback Junction Transistor Amplifiers

DR. HERBERT HELLERMAN*

The design of amplifier circuits having large amounts of feedback, such as are encountered in analog computer applications, requires careful control of the gain-phase characteristics of the loop gain transmission if good performance without instability is to be achieved. A realistic design procedure must depend on the constraints imposed by the high frequency characteristics of the transistor expressed as an equivalent circuit. This must be simple, although highly approximate since several coupled transistors are involved in one circuit and an accurate but complicated single transistor equivalent circuit makes calculations for the entire amplifier too cumbersome for practical value. This article justifies (experimentally and theoretically) an approximate transistor equivalent circuit suitable for design purposes. Also discussed are simple interstage networks for control of the loop transmission, and considerations for determining the impedance level in the feedback path.

[Tear sheets of this article are available on written request]

THE USE OF INVERSE FEEDBACK to produce high quality amplifiers is a technique well known to electronic and control system engineers. The emphasis in this article is on that special class of amplifier found in analog computers, active filters and high quality control circuits. They can, for the most part, be described as requiring large feedback to be present over the useful frequency band which is usually narrow compared to the bandwidth of the amplifying device used in the circuit. However, because of stability considerations the large loop gain in the pass band must be reduced to zero *db* before its excess phase shift becomes 180 degrees due to the high frequency properties of the active part of the circuit. Since realizable networks can be designed to bring the gain down without excessive phase shift only within definite limits, it is evident that the maximum feedback and hence the maximum network performance at the low frequencies is fundamentally limited by the high frequency behavior of the amplifying devices.

The intimate relation sketched above between the forward amplifier high frequency characteristics and maximum feedback is well known in the Art. It is the purpose of this article to discuss the application of this general knowledge to the case where junction transistors are used to provide the amplification. The high frequency characteristics of the triode junction transistor will, therefore, be described in some detail. However, before entering into a discussion of this important subject it is well to define a term which plays a key role in the theory.

The Loop Gain Transfer Function[1]

Single loop feedback amplifiers may be studied with the aid of the loop gain transfer function or return ratio. A system is of the single loop type if there is but a single path from the output back to the input. Although this condition is satisfied in most vacuum tube circuits at low frequencies, it is not strictly true in the transistor case. The reason for this is that there is internal feedback within the transistor which cannot in general be neglected. Thus, in a transistor feedback amplifier having a single external loop, there are really two feedback paths, one through the external loop, the other back through the transistors. Fortunately, however, it is often possible to consider the overall internal feedback of several transistors in cascade as being very small. This is especially true for the most common case of cascaded grounded emitter stages. This can be understood by considering the entire active part of the amplifier as a four terminal network and inspecting the parameter which is a measure of the feedback. Although z_{12}, y_{12} or h_{12} will suffice for this purpose (since if any one of these is zero the others will be zero also), h_{12} is perhaps the most significant in the transistor case since its definition most nearly coincides with the impedance conditions met in the transistor cascade arrangement. The h_{12} of the overall network declines very rapidly as the number of stages increases, so for three or more stages the overall internal feedback is small and can often be neglected. This justifies the use of single loop theory in most cases of practical importance.

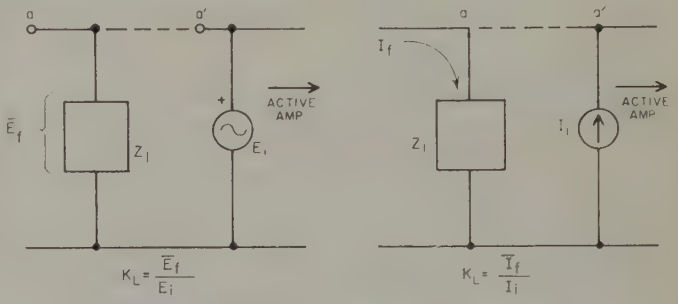

Fig. 1—Loop Gain Transfer Function

The loop gain transfer function or return ratio for a single loop system may be defined with the aid of *Fig. 1*. On a voltage basis, (*Fig. 1a*), we consider the lead *a-a'* normally in series with the input of the active portion of the amplifier to be broken. On one

*The material presented here is the outcome of work done at Syracuse University. Dr. Hellerman is now associated with the I.B.M. laboratories at Peekskill, New York.

side of the break a voltage E_1 is applied and the voltage E_f due to tranmission around the loop is determined. The loop gain tranfer function is defined as

$$\overline{K}_L = \frac{\overline{E}_f}{\overline{E}_1} \qquad (1)$$

As seen in *Fig. 1a,* the circuit is considered with the normal input impedance to the active amplifier, Z_i, located on the left side of the break. This is an important point in transistor amplifiers where the first transistor input impedance cannot, in general, be neglected. *Fig. 1b* shows how the loop gain transfer function may be evaluated on a current basis. It is easily shown that the current and voltage loop gains are identical so it is immaterial how the ratio is determined.† In transistor circuits it is often convenient to make calculations on a current transfer basis and therefore the loop gain as determined by considering the current form may be somewhat simpler to apply.

The Junction Transistor High Frequency Equivalent Circuit

As mentioned above, because of stability considerations, the high frequency characteristics of the transistor impose the fundamental limitations on the maximum feedback which can be used in the circuit. A critical step in the stability problem, is, therefore, the determination of a suitable transistor high frequency equivalent circuit. In this regard it is important to recognize that a compromise between complexity and accuracy is essential if a suitable design procedure is to be arrived at. A highly accurate but complicated equivalent circuit of the individual transistor will be nearly useless if it is to be used in the design of a multistage amplifier.

The central problem in the derivation of the equivalent circuit of a transistor is to relate the terminal currents and voltages to the physical processes, i.e., the flow of carriers within the transistor. This is usually done in two parts as indicated in *Fig. 2.* The physical processes in the transistor are divided into two classes, "intrinsic" and "extrinsic".[2] Included in the extrinsic class are the ohmic resistances to current flow in the semiconductor regions and in the lead to semiconductor contacts. Although there are three such extrinsic resistances, only the one associated with the base is usually of great importance in high frequency behavior. The reason is that the extrinsic base resistance r_b' tends to be large because it includes the narrow base width as one dimension of its area. Also, r_b' is in a feedback position in the low impedance input circuit. At high frequencies in the case of grown junction transistors, the base spreading resistance must be replaced by an impedance representation as has been shown by Pritchard and Coffee.[3]

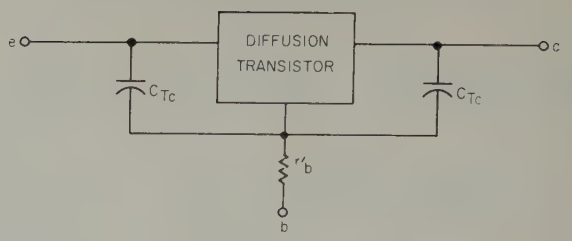

Fig. 2—Configuration For Small Signal Equivalent Circuit For Alloy Junction Transistor

Another phenomenon coming under the extrinsic category is the junction capacitance. This is due to the depletion of the charged carriers at the junction leaving a fixed double charge layer due to the ionized atoms. Since any change in junction voltage must be accompanied by a change in the width of the charge layer, the junction constitutes a capacitance. This capacitance is dependent upon the junction bias voltage, becoming smaller for increasing bias voltage. Although there are two junctions, and hence two junction capacitances (C_{Te}, C_T), the collector capacitance is of greatest importance since it appears both in the high impedance output circuit and in a feedback position in most transistor circuits.

In addition to the extrinsic phenomena and their representations as circuit elements as discussed above, there exists the important diffusion phenomena which are represented in circuit form by the "intrinsic" parameters. The diffusion equation for the transport of carriers has been solved and simplified by Early.[2] The solution involves hyperbolic functions of the frequency and is expressed in the form of "*y*" parameters for the connection of the transistor where the base is the common terminal. The combination of these intrinsic parameters with the extrinsic elements discussed earlier gives a remarkably complete circuit model of the transistor.

Having obtained from the device workers a circuit which represents the device, the next step is to convert this to a form most useful to the circuit engineer. Since the common emitter connection is the most widely used basic configuration in low frequency junction transistor applications because of its high gain, parameters most convenient for this configuration are selected. Of the many ways the common emitter circuit may be represented, one of the most useful is in terms of the "*h*" or hybrid parameters defined through the signal equations

$$\begin{aligned} \overline{V}_{be} &= h_{11e}\,\overline{I}_b + h_{12e}\,\overline{V}_{ce} \\ \overline{I}_c &= h_{21e}\,\overline{I}_b + h_{22e}\,\overline{V}_{ce} \end{aligned} \qquad (2)$$

The common emitter "*h*" parameters are a good choice for the following reasons:

†This may be seen from the fact that the definition of loop gain makes the output and input terminations of the return-ratio network identical. In this case voltage and current transfer ratios are the same.

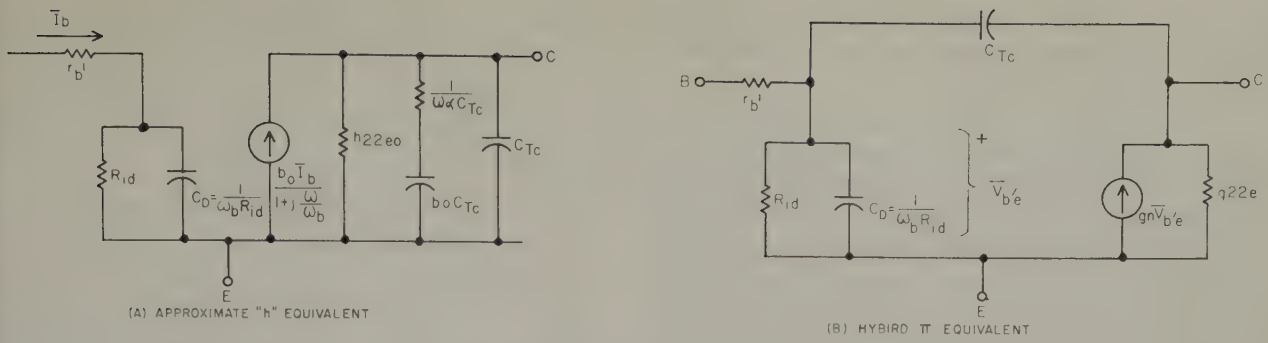

Fig. 3—Common Emitter Equivalent Circuits

1. They are defined in terms of input open circuit, output short circuit conditions which are compatible with simple bias arrangements.
2. In a cascade connection of common emitter circuits, since $h_{11e} \gg \frac{1}{h_{22e}}$, h_{22e} may often be neglected in the interstages and each individual stage is then considered as a current amplifier.

When the extrinsic and intrinsic circuit representations are combined in the circuit of *Fig. 2*, the h parameters of Eq. (2) are then obtained. These still contain complex hyperbolic functions of frequency. However, if the frequency range is suitably restricted as stated specifically below, the four h parameters may be written as

$$h_{11e} = r'_b + \frac{R_{id}}{1 + j\frac{\omega}{\omega_b}}$$

$$h_{21e} = \frac{b_o}{1 + j\frac{\omega}{\omega_b}} \qquad (3)$$

$$h_{12e} = h_{12eo} + \frac{j\omega C_{Tc} R_{id}}{1 + j\frac{\omega}{\omega_b}}$$

$$h_{22e} = h_{22eo} + \frac{j\omega\, b_o\, C_{Tc}}{1 + j\frac{\omega}{\omega_b}} + j\omega C_{Tc}$$

where

R_{id} = Diffusion part of h_{11e} at low frequencies.
b_o = h_{21e} at low frequencies.
h_{12eo} = h_{12e} at low frequencies.
h_{22eo} = h_{22e} at low frequencies.

$\frac{\omega_b}{2\pi}$ = 3 *db* cut-off frequency of h_{21e}

The above represents the junction transistor to frequencies satisfying

$$f < b_o \frac{\omega_b}{2\pi}$$

The above four h parameters may be shown in circuit form. However, in most cascade arrangements where the load impedance on each device is small, h_{12e} may be neglected, and the three parameter h equivalent as shown in *Fig. 3a* is most useful. It is, of course, true that other circuit representations besides the h equivalent may be used to represent the terminal properties of the transistor. *Fig. 3b* shows the "hybrid π" equivalent suggested by Giacolletto[4] and also used by circuit designers. This representation has the conceptual advantage that it resembles the high frequency equivalent of the vacuum tube (except for r_b' and R_d).

It is of interest to note the appearance of ω_b in all of the above equations.

To summarize, the frequency behavior of a junction transistor over a range from very low frequencies to frequencies somewhat lower than the alpha cut-off frequency, $\frac{1.2 b_o \omega_b}{2\pi}$ may be described by an equivalent circuit which contains lumped constants. The form of equivalent circuit most directly applicable to the problem at hand is based on the common emitter h parameters which can be expressed in terms of the parameters r_b', b_o, ω_b, R_{id}, C_{Tc} and h_{22eo}. Of these, the first four are of primary importance in a cascade connection of common emitter or common base stages or when the load impedance on the transistor is small. Because of the low impedance levels met in transistor circuits, distributed capacitances do not limit the frequency response of most transistor circuits of the type to be discussed, where typical values of $\omega_b/2\pi$ range from 10 to 200 *kc*. Of course, this statement can be expected to be less true as better devices become available.

The Transistor Stability Problem

If a feedback amplifier consisting of 3 or more cascaded identical common emitter stages and a resistive feedback network is constructed, the previous theory indicates that at least 270° phase shift around the loop may be expected and the circuit will therefore become unstable with less than 18 *db* of low frequency feedback. Although this statement neglects the frequency behavior of the input impedance of the active portion of the amplifier, the 18 *db* figure does give a realistic idea of the seriousness of the situation. Even though the loop gain function has a form similar to the case of cascaded resistance coupled tube cir-

cuits, from the point of view of designing stabilizing networks the following points in the transistor case should be clearly understood.

1. The principal source of the degradation of response is in the diffusion process within the transistor and is not available to the circuit designer.
2. The loading effect of each transistor on the preceding one is complex and must in general be taken into account in the design of stabilizing networks.

If the loop gain function is of the minimum phase type (and this is true in any ladder network), then as has been discussed extensively by Bode, the phase shift response may be found from the amplitude response. Attention can the be properly centered upon the amplitude response function. If the network is of the low pass *R-C* type, then the poles and zeros of the response function will lie on the negative real axis of the complex s-plane. The amplitude response function for the loop gain, in *db*, will then have the form

$$K_L(\omega) = K_{LO} + 10 \log_{10} \left[\frac{(1+\omega^2 T_1^2)(1+\omega^2 T_2^2)\ldots(1+\omega^2 T_n)}{(1+\omega^2 T_a)(1+\omega^2 T_b^2)\ldots(1+\omega^2 T_L^2)} \right] \quad (4)$$

where K_{LO} is the zero frequency loop gain in *db*. A good deal of information about such a function may be given in simplified form through the use of the straight-line approximation or Bode diagram. The diagram consists of straight lines with various slopes. Slopes of —6 *db* per octave indicate —90° phase shift (or one excess pole active), a —12 *db* per octave slope indicates —180° phase shift or two poles active over the frequency range, etc. Regions of zero slope on the diagram indicate no net poles active while +90° phase shift regions show up as +6 *db* per octave slopes. The accuracy of the straight line representation depends upon the degree of separation of the time constants and has been discussed in the literature.[5]

The purpose of the stabilizing networks is to bring the loop gain to unity (or zero *db*), before the phase shift becomes 180°. This means that everywhere above the intersection of the zero *db* line with the response curve the slope should be less negative than —12 *db* per octave.

The addition of the simple series circuit R_s–C_s to the common emitter circuit as shown in *Fig. 4* can help to accomplish the required attenuation characteristic.

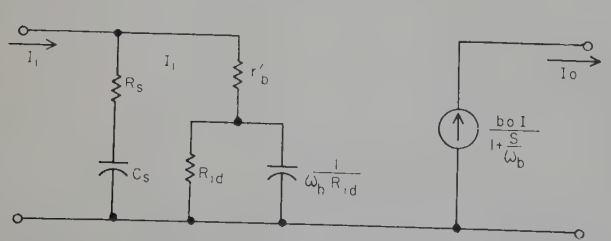

Fig. 4—Simplified Single Stage Equivalent Circuit With Shunt R-C Interstage

The complex current transfer function subject to the reasonable approximations indicated is

$$\frac{\bar{I}_o}{\bar{I}_i} = b_o \frac{(1+jnx)}{(1+jmx)(1+jnx)} \quad (5)$$

where

$$x = \frac{\omega}{\omega_b}$$

$$m = R_{id} C_s \omega_b$$

$$n = \frac{R_s + r'_b}{R_{id}}$$

$$p = R_s C_s \omega_b$$

It is assumed that $R_{id} \gg R_s, r'_b$

$$R_{id}\, C_s \gg \frac{1}{\omega_b}$$

The Bode diagram of this stage is shown in *Fig. 5*. It is seen that the effect of the added network is not only to bring the gain down but also to extend the

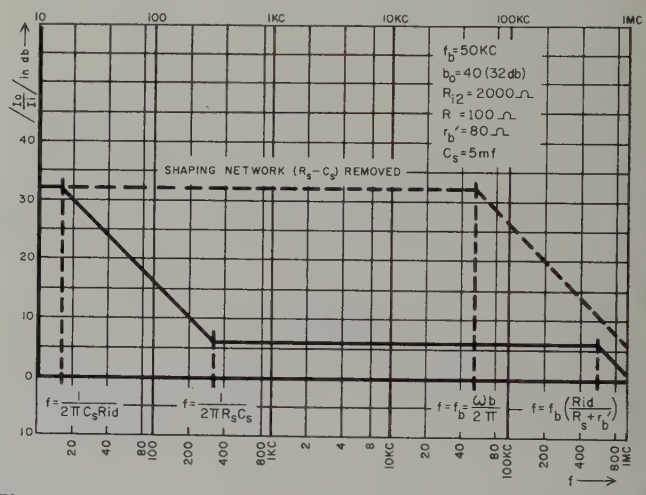

Fig. 5—Straight Line Approximation to Response of Fig. 4.

high frequency point at which the phase shift comes near 90°. The extent to which the high frequency break point is moved out is closely related to the amount of attenuation one has permitted between the low and intermediate frequency regions. If r'_b were zero a direct trade of gain for bandwidth between the last break points using the above circuit would be possible (this is the case in simple vacuum tube interstages of this type). It can be shown that the direct exchange can be obtained even with non-zero r'_b if, instead of the circuit R_s-C_s as shown in *Fig. 4*, a series R_s-C_s-L_s combination is used. The inductance should be adjusted to satisfy

$$L_s = \frac{r'_b R_s}{\omega_b (R_{id} + r'_b)} \quad (6)$$

From the above it is evident that r'_b is an important high frequency parameter in stability considerations. As mentioned earlier the equivalent circuit with real r'_b is valid for alloy junction transistors. For grown junction units the quantity corresponding to r'_b is

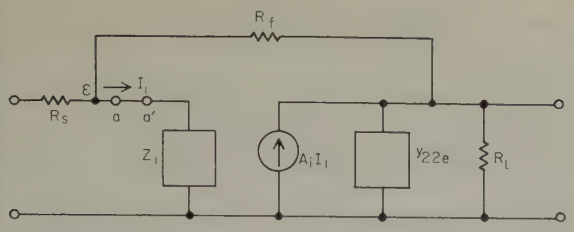

Fig. 6—Voltage Operational Amplifier

complex and is not a rational function of $j\omega$ so it is difficult to give a simple lumped circuit representation for this impedance over a wide frequency range. However, the general behavior of h_{11e} for grown junction transistors may be described as an impedance magnitude that is down 3 *db* from its low frequency value at about 1.7 f_b and decreases thereafter at a —3 *db* per octave rate while maintaining a constant phase shift at about 45° lagging. It is difficult to compare this type of response with the alloy junction case at least with a view towards deciding which is the more favorable. The smaller slope of h_{11e} in the grown junction case is unfavorable compared to the —6 *db* per octave slope found in this quantity over a wide frequency range in alloy junction transistors. However, the grown junction units have an advantage in that h_{11e} continues to fall with frequency beyond the point where the slope becomes zero due to the constant r'_b in the alloy junction case.

Illustrative Design

The principles discussed above will be applied to the structure of *Fig. 6*. This type circuit is often used as an operational amplifier in analog computer circuits. The analysis will concentrate on the network characteristics of the circuit, other problems such as drift will not be considered here.

The loop gain for this configuration may be expressed as

$$K_L = A_i \left(\frac{Z'_L}{R_f + Z'_i}\right)\left(\frac{R_s}{R_s + Z_i}\right) \qquad (7)$$

where

A_i = Short circuit current amplification from ϵ to 0.

Z'_L = Effective shunt impedance of the output circuit including the output impedance of the last transistor.

Z_i = Input impedance measured at the first transistor

Z'_i = Parallel combination of Z_i and R_s.

An important design parameter is the impedance level of the feedback resistors R_f and R_s. Since the objective is to make the loop gain as large as possible, it is desirable to adjust R_s and R_f so as not to waste the transistor gain available. If the impedances R_s and R_f are too large, loop gain is lost due to the shunting effect of Z_i. If R_s and R_f are too small, the loop gain suffers due to the reduction of Z'_i. An optimum impedance level criterion has been derived by maximizing Eq. (7) subject to certain reasonable assumptions about the loading on the circuit.[6] Although the details of this need not concern us here, the results indicate that an efficient design will use smaller resistors in the feedback path than is normally encountered in vacuum tube circuits (R_f and R_s should be on the order of 10 to 100 kilohms instead of the megohm levels found in tube amplifiers.‡)

From Eq. (7) it is evident that in addition to the frequency variation of the current gain, the frequency properties of the output circuit and the input impedance of the active amplifier must also be taken into account. Although it is tempting to try to obtain a large loop gain in the passband by using a high resistance load, this would result in the collector capacitance of the last stage playing a limiting role in the stability problem. From *Fig. 3*, the collector to base capacitance C_{Tc} is seen to appear in the output circuit of the common emitter stage as $b_o C_{Tc}$ in series with a resistance $\frac{1}{\omega_\alpha C_{Tc}}$. However, the equivalent circuit of *Fig. 3* is based on the h parameters which are defined for the input open, output shorted condition. At the higher frequencies the input circuit to each transistor consists of the small shunt resistance of the compensating network. Therefore, y_{22e}, the output admittance of the transistor with input shorted is a better approximation to the frequency behavior of the transistor output impedance and it is this quantity which is used in *Fig. 6*. For the case of constant r'_b, y_{22e} can be represented by the same type of equivalent circuit as shown for h_{22e} in *Fig. 3* except that the capacitance $b_o C_{Tc}$ should be replaced by $\gamma b_o C_{Tc}$ where

$$\gamma = \frac{R'_b}{R'_b + R_{id}}$$

(R'_b is the sum of r'_b and the resistance R_s of the compensating network). In the case of grown junction transistors the situation is qualitatively the same but due to the complex nature of Z'_b the above theory cannot be expected to hold exactly. Since γ is smaller than unity, the collector capacitance of the output transistor does not become an important factor until frequencies approaching

$$f = \frac{1}{2\pi\gamma\, b_o C_{Tc} R_L} \qquad (8)$$

Fig. 7 shows a circuit diagram of an amplifier using five junction transistors. The circuit as it stands could be used as a high accuracy inverting or summing amplifier in a 60 *cps.* computing system. If the *R-C* bias circuits in the emitters of T_3 and T_5 are replaced by breakdown diodes or a third power supply, the circuit

‡ The optimum impedance level is given by

$$R_s = \sqrt{Z_i Z_o \frac{k+1}{k}}$$

Where Z_o is the open loop output impedance and k is $\frac{R_f}{R_s}$. It is assumed the load on the amplifier is iterative, i.e., equal to R_s.

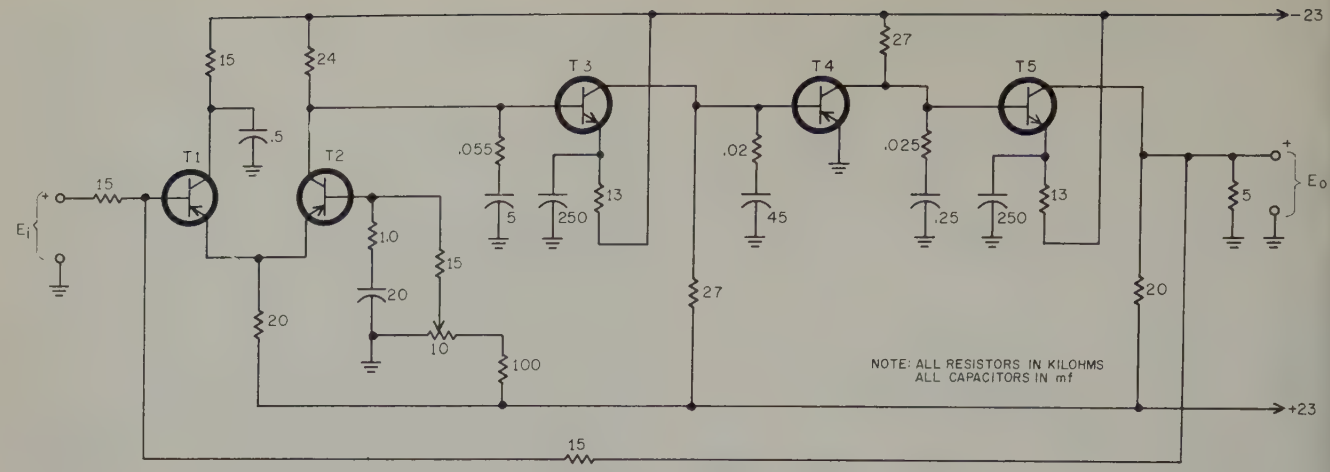

Fig. 7—Circuit Diagram For 5 Transistor Amplifier

would function as a high performance *d-c* amplifier. The possibility of using alternate *p-n-p* and *n-p-n* transistors to eliminate the need for interstage resistance networks is an advantage of transistor over vacuum tube circuits. The input circuit is an emitter coupled amplifier. This configuration was chosen because of its drift reduction possibilities and the fact that a chopper signal can be easily introduced on the base of T_2. The transistors T_3, T_4 and T_5 may be considered in the common emitter connection above 10 *cps*.

The stability and frequency response of the amplifier is dependent upon the characteristics of the transistors which are shown tabulated in Table I.

Table I

Measured Network Parameters of Transistors at 1000 cps. ($|V_c| = 5v$, $I_e = 1$ ma)

Transistor No. in Circuit	Type	b_o	f_b(kc)	(h_{11e})
1	2N43	56	14	2100
2	2N43	50	14	1850
3	TI201	36	74	1200
4	2N204	92	8.7	3300
5	T1201	54	54	2000

The loop gain transfer function can be written as

$$K_L = K_\epsilon \left(\frac{Z_i}{R_f + Z'_i}\right)\left(\frac{R_s}{R_s + Z_i}\right) \qquad (9)$$

Eq. (9) is a useful form for comparison with experiment and is entirely equivalent to Eq. (7). The error point gain K_ϵ defined as the ratio of E_o to E_ϵ is easily measured and K_L may be determined through Eq. (9). A plot of the loop gain response from measured data of K_ϵ as well as the calculated response using values from Table I is shown in *Fig. 8*. In making the calculations it was necessary to take into account the effects of the operating points of the transistors on their small signal parameters. The design of the interstage networks is straightforward, the break points are staggered so that the slope of the attenuation is kept more positive than —12 *db* per octave. The last breakpoint corresponding to a zero in the loop gain was chosen at the frequency at which the high frequency properties of the transistors begin to become important. This is at about 25 *kc*. where the loop gain is 12 *db* and the attenuation characteristics above this frequency may be described using Eq. (7). The following quantities are of importance at frequencies above the last breakpoint of the interstages.

1. The current gain A_i has a simple pole giving a breakpoint at 14 *kc*. This is due to the current gain response of T_1.
2. The pole mentioned in 1. is cancelled by a zero due to the frequency variation of Z_i and is replaced by a pole having its breakpoint at about 26 *kc*.
3. The effect of the interstage networks is to move those breakpoints of the current gain which occur at the higher frequencies out to several times the corresponding values of $\frac{\omega_b}{2\pi}$. This is true for the alloy junction transistors. For the grown junction units the high frequency current gain starts to drop at $\frac{\omega_b}{2\pi}$ at the rate of —3 *db* per octave and the limiting phase shift is —45°.

The above discussion describes the important parameters which determine the high frequency behavior of the loop gain.

The measured closed loop response (both amplitude and phase) is shown in *Fig. 9*. The amplitude response is flat within 3 *db* to 64 *kc*. and the phase shift is smaller than .5 degrees to 600 *cps*.

These numerical results are of course dependent upon the properties of the transistors used and better performance than reported above is readily possible by using higher frequency transistors. If appreciable power were required in the output so that a power transistor was needed in the last stage, then the design procedure should take into account the poor high frequency performance of most power transistors. In this case a simple procedure is to design the interstage networks to provide all their attenuation before

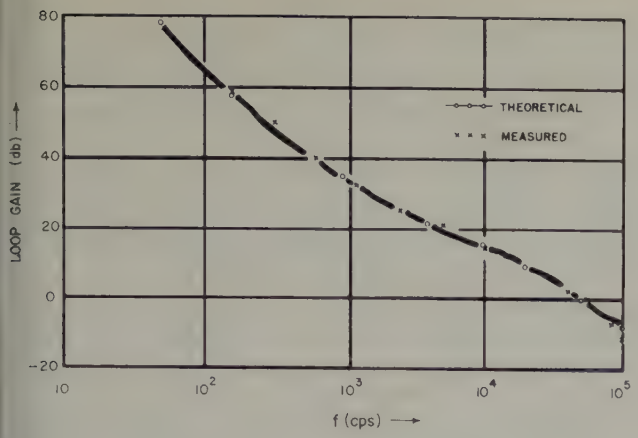

Fig. 8—Loop Gain Response of Amplifier of Fig. 7.

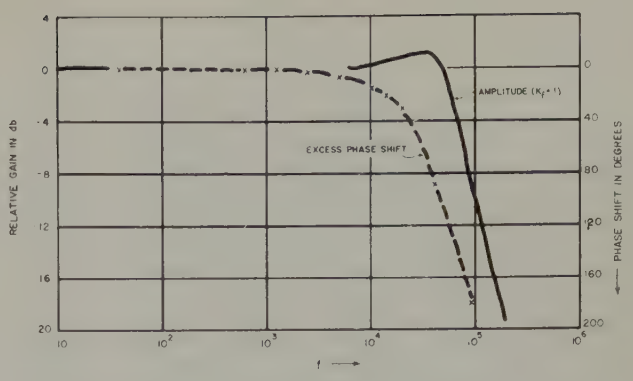

Fig. 9—Closed Loop Response of Amplifier of Fig. 7.

the cut-off frequency of the power transistor. However, the loop gain need not be brought to zero *db* at this frequency. The —6 db per octave roll-off of the power transistor can safely dispose of the several *db* of gain before the other circuits add the critical phase shifts.

Acknowledgement

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Static Characteristics of Transistors

A. W. CARLSON*

The effects of various voltage and current parameters on the operation of transistors are of interest in order to predict behavior at conditions other than those specified in the manufacturer's data. In this article such effects are described and illustrated by nine sets of characteristic curves for the basic transistor configurations. The discussion is introduced by showing first an ideal transistor, and then adding to it external elements representing base lead resistance and leakage resistance shunting the collector-base junction in order to closely approximate an actual transistor.

[Tear sheets of this article are available on written request]

THE D-C OR STATIC CHARACTERISTICS of transistors are presented by the manufacturer in the form of charts showing the output characteristics, input characteristics and transfer characteristics. The output characteristics are plots of collector current versus collector voltage with either input current or input voltage as a parameter and are analogous to the plate characteristics of a vacuum tube. The output characteristics may be for the common-base or common-emitter configurations with the latter being the more popular. The input characteristics are usually in the form of input voltage and current with collector voltage as a parameter. A curve showing large-signal collector-to-base current gain (beta) as a function of collector current is usually part of the data characterizing power transistors.

Transistors are not unilateral devices as are vacuum tubes at low frequencies. For example, the output

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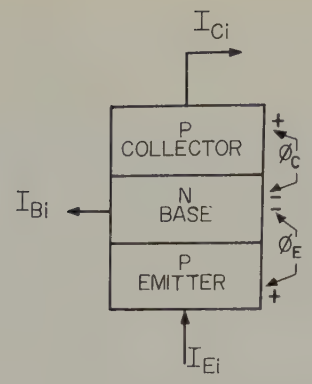

Fig. 1—Ideal transistor showing the positive directions of currents and voltages.

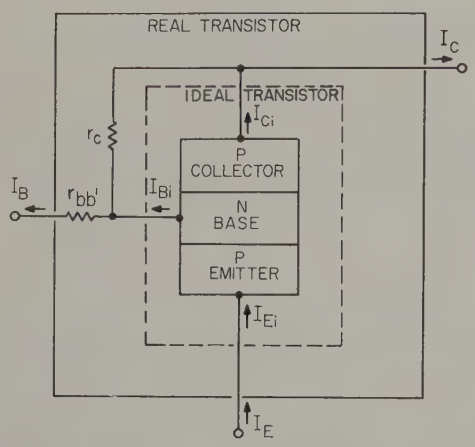

Fig. 2—Elements added to the ideal transistor as an approximation to a real transistor.

impedance of a transistor is dependent upon the source impedance. Thus the output characteristics with input current as a parameter (infinite source impedance) may be vastly different from the output characteristics with input voltage as a parameter (zero source impedance).

The transistor characteristics are usually given for some particular temperature such as 25°C. At other temperatures the characteristics differ mostly in the form of being shifted in the *V-I* plane.

An understanding of the relationships of voltages and currents in the transistor and the effects of temperature variations is important in order to predict transistor behavior for conditions other than those specified in the manufacturer's data. The situation is analogous to that of the pentode vacuum tube where the plate characteristics are presented for a constant screen voltage. Here a knowledge of vacuum tube theory enables one to determine the effects of operation at other values of screen voltage.

In power applications transistor voltages and currents vary widely. Small signal equivalent circuits based on small variations about an operating point are not really applicable to power amplifiers. They may be useful in making comparisons between circuits or in providing an insight to circuit performance but for detailed representation of the large signal conditions they are inadequate. Large signal non-linear equations may be used to represent the transistor.

Ideal Current-Voltage Relationships

Ebers and Moll have shown that for the "intrinsic" or ideal transistor the relationships between currents and voltages may be expressed as follows.

$$I_{Ei} = \frac{I_{Eo}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_E} - 1) - \frac{\alpha_I I_{Co}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_C} - 1) \quad (1)$$

$$I_{Ci} = \frac{\alpha_N I_{Eo}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_E} - 1) - \frac{I_{Co}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_C} - 1) \quad (2)$$

$$I_{Bi} = I_{Ei} = I_{Ci} = \frac{(1 - \alpha_N) I_{Eo}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_E} - 1) + \frac{(1 - \alpha_I) I_{Co}}{1 - \alpha_N \alpha_I} (e^{\wedge \varphi_C} - 1) \quad (3)$$

The positive directions of voltages and currents are chosen as shown in *Fig. 1* for a *p-n-p* transistor. The same equations hold for *n-p-n* transistors with all voltages and currents reversed. In these equations I_{CO} is the collector current in the reverse biased collector-base junction for zero emitter current and I_{EO} is the current in the reverse biased emitter-base junction for zero collector current. Both I_{EO} and I_{CO} are taken as positive quantities. α_N is the short circuit *d-c* collector-emitter current gain $= \left(\frac{I_C - I_{Co}}{I_E}\Big|_{V_C}\right)$ and α_I is a similar current gain with the roles of emitter and collector interchanged, and has a value of about 39 V^{-1} at 25°C. $\wedge = \frac{q}{kT}$. ϕ_E and ϕ_C are voltages across the emitter-base and collector-base junctions. The alphas, I_{E0} and I_{C0} are related by $\alpha_I I_{C0} = \alpha_N I_{E0}$. The subscript "*i*" has been used to indicate that the equations apply to an ideal transistor.

From Equations (1), (2), and (3) it is seen that I_C may be expressed in terms of I_{Ei} and I_{Bi} as

$$I_{Ci} = \alpha_N I_{Ei} - I_{Co} (e^{\wedge \varphi_C} - 1) \quad (4)$$

and

$$I_{Ci} = \frac{\alpha_N}{1 - \alpha_N} I_{Bi} - \frac{I_{Co}}{1 - \alpha_N} (e^{\wedge \varphi_C} - 1) = \beta I_{Bi} - (\beta + 1) I_{Co} (e^{\wedge \phi_C} - 1) \quad (5)$$

When the collector junction is reverse biased by a few tenths of a volt, $e^{\wedge \phi_C}$ becomes negligibly small and may be dropped from the equations.

All of the above equations apply to an ideal transistor and as such do not adequately represent actual transistors. For instance, they indicate that when the collector junction is reverse biased, the collector current is independent of the collector voltage, which is equivalent to saying that the collector impedance is infinite.

Representation of the Real Transistor

The real transistor may be approximated more accurately by adding external elements to the ideal transistor, the most important being the base lead resistance, $r_{bb'}$, and a leakage resistance, r_c, shunting the collector-base junction as in *Fig. 2*. A similar leakage resistor could be shown shunting the emitter-base junction but for most applications the emitter-base junction is forward or only slightly reverse biased, justifying its omission. The base resistance, $r_{bb'}$, varies somewhat with collector current and temperature but will be assumed constant. It decreases somewhat as collector current increases and may increase or decrease with temperature rise, depending upon the base material and the operating temperature. It will be assumed that maximum reverse collector voltages are sufficiently below the breakdown voltage so that avalanche multiplication effects may be ignored. In *Fig. 2* the currents having the subscript "*i*" are those for the ideal transistor and those without subscripts refer to real transistors. The leakage resistance, r_c, will be assumed to be very much larger than the base lead resistance, $r_{bb'}$. Small series resistances can be inserted in series with the emitter and base leads to represent resistance of the emitter and collector regions but for the power transistors under consideration these are negligibly small.

Common-Base Characteristics

The common-base collector characteristics as obtained from *Fig. 2* are shown in *Fig. 3*. The effect of $r_{bb'}$ is to depress the breakpoints of the constant I_E curves below the current axis. The transistor in the common-base configuration may operate in the active region with no external collector supply voltage or even slightly reversed collector supply voltage due to the voltage drop across the base lead resistance. The effect of the collector leakage resistance is to make the slope of the constant I_E curves finite in the active region—the output resistance being approximately r_c. When the emitter current is zero or the emitter reverse biased, the transistor is said to be cut off. When both emitter and collector junctions are forward biased, the transistor is operating in the saturated region. The cutoff and saturated regions are indicated by shaded areas in *Fig. 3*. In the saturated region the slope of the constant I_E curves is the sum of the impedance of the forward biased collector junction and $r_{bb'}$ and thus approximately $r_{bb'}$.

The common-base collector characteristics with V_E as a parameter are shown in *Fig. 4*. The slope of the constant V_E curves (output impedance) varies widely in the active region from r_c for negative V_E and approaches $\frac{r_c}{\beta+1}$ as collector current is increased. The constant V_E curves are not linear in the active region as are the constant I_E curves, since the slope decreases with increasing collector voltage. Nor is the transconductance $\left(\frac{dI_C}{dV_C}\Big|_{V_C} = G_M\right)$ constant but varies from $\Lambda\left(I_c - I_{cs} - V_c/r_c\right)$ at low values of collector current, approaching $\frac{\beta}{r_{bb'}}$ at high values of collector current.

The variation in transconductance with collector current is reduced by the drop-off in β with increasing collector current, making the transconductance more nearly constant than it would be if β were independent of collector current. In the saturated region, the output resistance is very low, approaching the sum of the forward resistances of the emitter and collector junctions and therefore may be only a fraction of an ohm for the larger values of V_E.

The input characteristic with V_C as a parameter is shown in *Fig. 5* for the collector junction reverse biased. The effect of V_C is to produce a family of

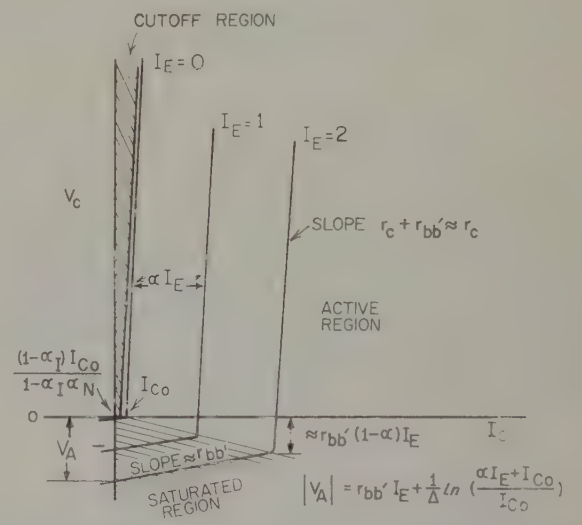

Fig. 3—Common-base collector characteristics with I_E as parameter.

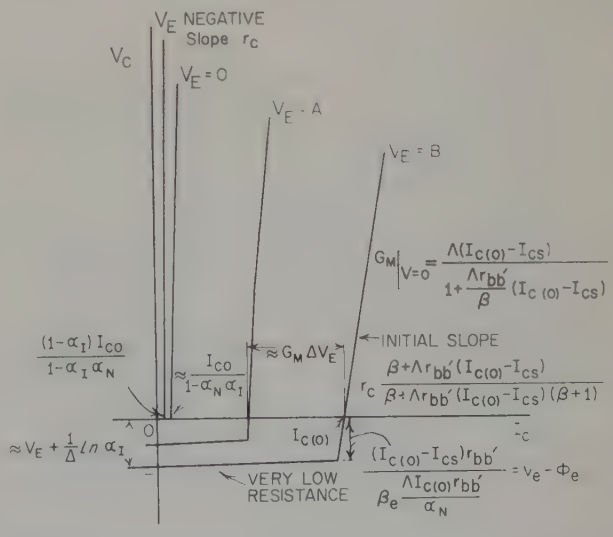
V_E NEGATIVE
Slope r_c
V_C
$V_E = 0$
$V_E = A$
$V_E = B$
$G_M|_{V=0} = \frac{\Lambda(I_{C(0)} - I_{CS})}{1 + \frac{\Lambda r_{bb'}}{\beta}(I_{C(0)} - I_{CS})}$
$\frac{(1-\alpha_I) I_{CO}}{1-\alpha_I \alpha_N}$
$\approx \frac{I_{CO}}{1-\alpha_N \alpha_I}$
$\approx G_M \Delta V_E$
INITIAL SLOPE
$r_c \frac{\beta + \Lambda r_{bb'}(I_{C(0)} - I_{CS})}{\beta + \Lambda r_{bb'}(I_{C(0)} - I_{CS})(\beta+1)}$
0
$I_{C(0)}$
$\approx V_E + \frac{1}{\Delta} ln \alpha_I$
$\frac{(I_{C(0)} - I_{CS}) r_{bb'}}{\beta_e} \frac{\Lambda I_{C(0)} r_{bb'}}{\alpha_N} = V_e - \Phi_e$
VERY LOW RESISTANCE

Fig. 4—Common-base collector characteristics with V_E as parameter.

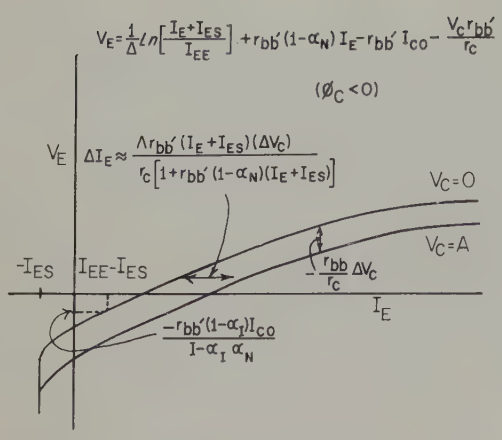
$V_E = \frac{1}{\Delta} ln\left[\frac{I_E + I_{ES}}{I_{EE}}\right] + r_{bb'}(1-\alpha_N) I_E - r_{bb'} I_{CO} - \frac{V_C r_{bb'}}{r_c}$
$(\phi_C < 0)$
V_E
$\Delta I_E \approx \frac{\Lambda r_{bb'}(I_E + I_{ES})(\Delta V_C)}{r_c[1 + r_{bb'}(1-\alpha_N)(I_E + I_{ES})]}$
$V_C = 0$
$V_C = A$
$-I_{ES}$
$I_{EE} - I_{ES}$
$-\frac{r_{bb}}{r_c}\Delta V_C$
I_E
$\frac{-r_{bb'}(1-\alpha_I) I_{CO}}{1-\alpha_I \alpha_N}$

Fig. 5—Common-base input characteristics with V_C as parameter.

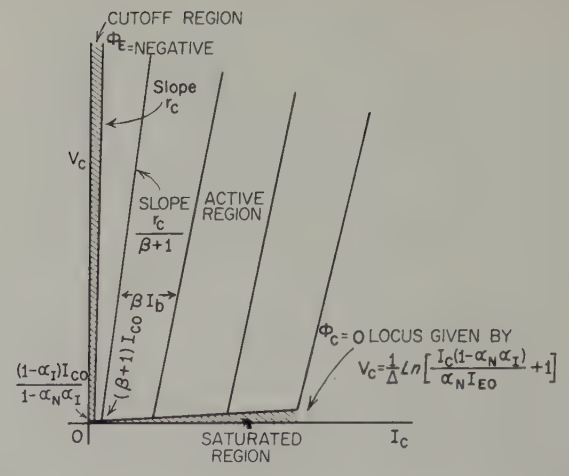

Fig. 6—Common-emitter output characteristics with I_B as parameter.

curves separated vertically by $\frac{-r_{bb'}}{r_c} \times \Delta V_C$. If $r_{bb'}$ were zero, or if r_c were infinite, then the input characteristic would be represented by a single curve. Actually the vertical displacement between the input characteristics may not be great in power transistors. For example, the $V_C = 0$ and $V_C = 10$ volt curves would be separated by .01 volt in a transistor having an $r_{bb'}$ of 10 ohms and an r_c of 10,000 ohms.

Common Emitter Characteristics

The common-emitter output characteristics with I_B as a parameter are shown in *Fig. 6*. In the active region, the slope of the constant I_B curves is $\frac{r_c}{\beta + 1}$ which is considerably lower than that of the constant I_E curves for the common base characteristics. It is also seen that the collector saturation current is increased by a factor of $(\beta + 1)$. When the transistor is cut off, the conditions are the same as in the common-base configuration. In the saturated condition the output impedance is very low (less than an ohm) and is made up of the sum of the forward impedances of the emitter and collector junctions. The collector voltage in the saturated region is also very low; it is the difference between the voltage across the collector junction and the emitter junction. This property of low collector voltage in the saturated region contributes to the efficiency of the transistor.

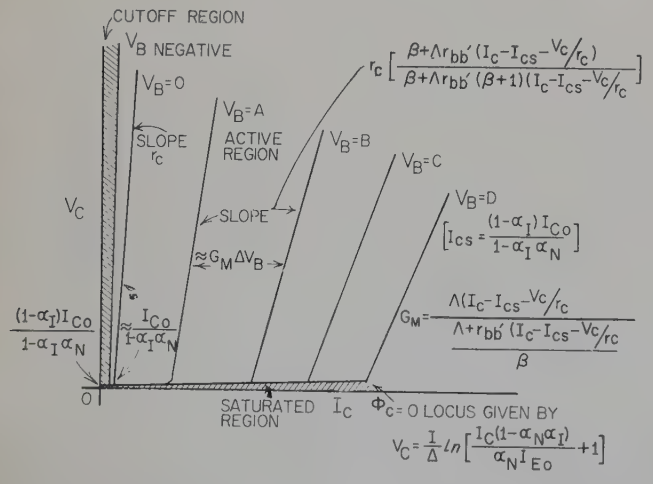

Fig. 7—Common-emitter output characteristics with V_B as parameter.

Figure 7 shows the common-emitter characteristics with V_B as a parameter. In the active region the characteristics are identical with those for the common-base with V_E as a parameter, i.e., the transconductance and the output resistance are the same. The output resistance varies from r_c for low values of collector current and approaches $\frac{r_c}{\beta + 1}$ for high values of collector current. Thus the output resistance for the common-emitter configuration for zero input source impedance (or for finite source impedances) is always higher than when driven from a current source. At high values of collector current, the output impedance is relatively independent of the input source impedance. In the saturated region the output impedance is essentially the same as that of *Fig. 6*.

The common-emitter input characteristic is sketched in *Fig. 8*. It is seen that as the base current is increased, changes in collector voltage have little effect on the input characteristic. It is also seen that the input resistance approaches $r_{bb'}$ as the base current is increased.

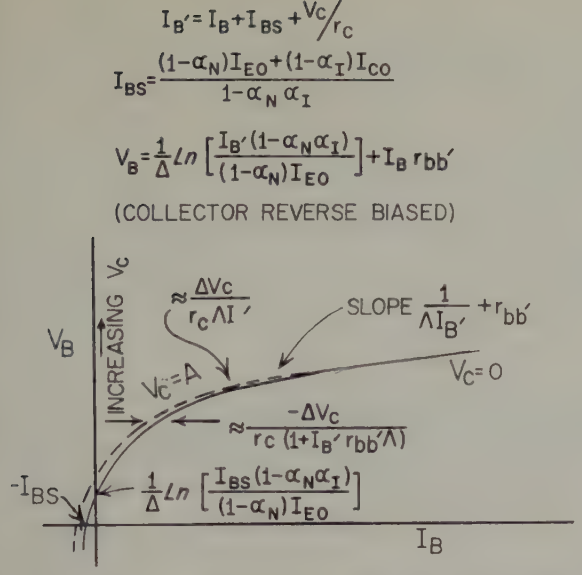

Fig. 8—Common-emitter input characteristics with V_C as parameter.

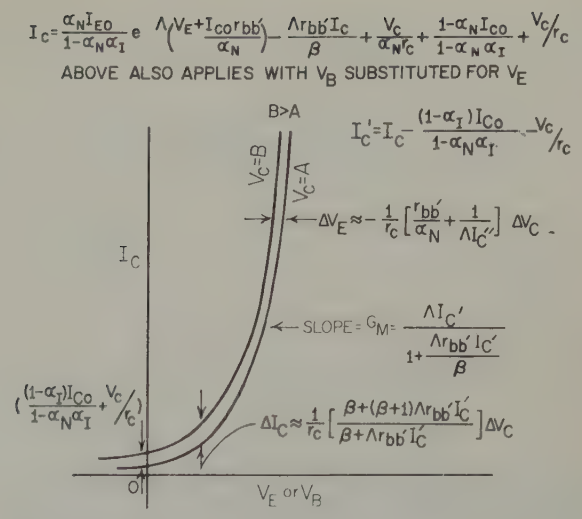
$I_C = \frac{\alpha_N I_{EO}}{1-\alpha_N\alpha_I} e^{\Delta\left(V_E + I_{CO} r_{bb'}\right)/\alpha_N} - \frac{\Delta r_{bb'} I_C}{\beta} + \frac{V_C}{\alpha_N r_C} + \frac{1-\alpha_N I_{CO}}{1-\alpha_N\alpha_I} + V_C/r_C$
ABOVE ALSO APPLIES WITH V_B SUBSTITUTED FOR V_E
B>A
$I_C' = I_C - \frac{(1-\alpha_I) I_{CO}}{1-\alpha_N\alpha_I} - V_C/r_C$
$V_C = B$
$V_C = A$
$\Delta V_E \approx -\frac{1}{r_C}\left[\frac{r_{bb'}}{\alpha_N} + \frac{1}{\Delta I_C''}\right] \Delta V_C$
I_C
SLOPE = $G_M = \frac{\Delta I_C'}{1 + \frac{\Delta r_{bb'} I_C'}{\beta}}$
$\left(\frac{(1-\alpha_I)I_{CO}}{1-\alpha_N\alpha_I} + V_C/r_C\right)$
$\Delta I_C \approx \frac{1}{r_C}\left[\frac{\beta + (\beta+1)\Delta r_{bb'} I_C'}{\beta + \Delta r_{bb'} I_C'}\right] \Delta V_C$
0
V_E or V_B

Fig. 9—Transfer characteristics for common-emitter or common-base configuration.

Transfer Characteristic

The transfer characteristic applicable to both common-emitter and common-base configurations is sketched in *Fig. 9*. The effect of increasing the collector voltage is to displace the transfer characteristic to the left and upward by an amount dependent upon collector current, current gain, base lead resistance, leakage resistance and the change in collector voltage. As the leakage resistance is increased, the shift in the transfer characteristic with a change in collector voltage is decreased. For the ideal transistor having infinite leakage resistance the transfer characteristic is independent of collector voltage. The drop off in β as the collector current is increased tends to make the voltage transfer characteristic more linear than it would be otherwise. At high collector current, the transconductance approaches $\frac{\beta}{r_{bb'}}$.

Common Collector Characteristics

The output characteristics for the common-collector configuration are shown in *Fig. 10* and *11* with I_B and V_B as parameters. From *Fig. 10* it is seen that the characteristics for constant I_B are practically the same as the characteristics for the common-emitter configuration with I_B as a parameter. The output characteristics of *Fig. 11* having V_B as a parameter show that the output impedance when driven by a low impedance source may be very low, approaching $\frac{r_{bb'}}{\beta + 1}$.

The linearity of the common-collector configuration is very good when driven by a low impedance source.

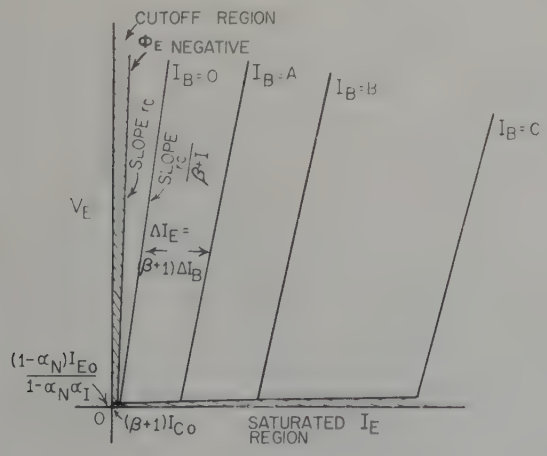

Fig. 10—Common-collector output characteristics with I_B as parameter.

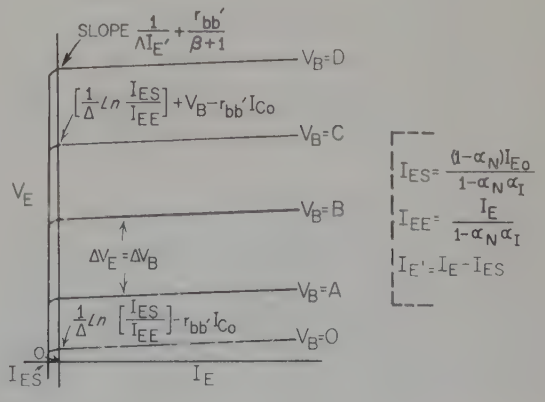

Fig. 11—Common-collector output characteristics with V_B as parameter.

Studies of Semiconductor Materials Using a Vacuum Microbalance

DR. S. P. WOLSKY*

In order to make reliable semiconductor devices, it is necessary to obtain information concerning the basic properties of the semiconductor materials. A very sensitive quartz microbalance housed in an ultra-high vacuum system is used in the investigation of germanium and silicon. A detailed description is presented of the microbalance, its associated apparatus, and the general experimental technique. Studies of sputtering, oxidation, and surface regeneration phenomena, as well as other applications of the microbalance, are discussed.

[Tear sheets of this article are available on written request]

IN ORDER TO DESIGN and make reliable semiconductor devices, it is necessary to possess information concerning the basic properties of the semiconductor materials. These properties may be separated into the general categories of (1) bulk and (2) surface. Although the bulk and surface properties may usually be studied independently, the observed behavior of a device is due to the net effect of both. In fact, as the understanding and ability to control bulk properties progressed, it became very apparent that the surface effects predominated to the extent that they essentially determined the device performance. With this recognition there came an increased effort devoted to the study of the surface properties of semiconductors, specifically germanium and silicon.

The surface investigations have been devoted to (1), a study of the electrical properties as determined, for example, from conductivity measurements,[1] and (2), the determination of the chemical nature of the surface, as deduced from kinetic and adsorption[2,3] experiments. The electrical behavior has been studied extensively so that the nature, density, and position of the energy states at the surface of germanium and silicon are fairly well known.[1,4,5] Unfortunately, the understanding of the chemical nature of these surfaces has not progressed as rapidly, with the result that it is still not possible to prescribe the treatment necessary for the attainment of the optimum surface for device operation.

Advantages of the Vacuum Microbalance

In considering the techniques available for obtaining adsorption and kinetic information, it is necessary to determine not only the most sensitive method but also that which could be readily adapted to other gas-solid studies. In this respect it is found that one of the most powerful experimental tools for the investigation of gas-solid reactions is the vacuum microbalance. The apparatus consists essentially of a very sensitive quartz microbalance which operates directly in vacuum and provides a continuous record of the experimental process. With this gravimetric technique, it is possible to work with samples of about 10 sq. cm. total surface area. The necessity of working with comparatively large area powdered or crushed samples demanded by the more conventional volumetric adsorption techniques is eliminated. Experiments with single crystal slices allow the detection of differences in behavior due to crystal orientation. Such studies have been very successfully performed using copper and zinc.[6] The vacuum microbalance apparatus also satisfies the requirement of versatility. As shall be illustrated below, although originally set up chiefly for the determination of the oxidation kinetics of germanium and silicon, the same apparatus has been used in this laboratory to determine the solubility of gases in solids[3] and the effect of positive ion bombardment on solids.[7]

Construction of the Balance

Since the technique is quite interesting it will be described in detail. The balance used in this work has been designed after that of Podgurski,[8] Gulbransen,[9] and Rhodin.[6] The very sensitive quartz microbalance has been set up in an ultra-high vacuum system. *Fig. 1* presents a schematic representation of the balance. The precision-made quartz beam (0.075 in. diameter) is supported on a 0.001 in. tungsten wire. The end supports are 0.0005 in. tungsten wire. The wires are joined to the beam and quartz frame with fused silver chloride. Iron cores sealed in small quartz sections allow external manipulation of the balance arrests by means of a small magnet. Static charge effects are eliminated by a ground connection to a conductive coating of platinum or gold evaporated onto the balance. The balance tubes are also grounded through an aduadag film. Weight changes are fol-

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lowed from observation of the deflection of the beam ends on the fixed scale in the eyepiece of a specially designed comparison-type microscope. The balance is calibrated by measuring the deflection from an observed zero point caused by known weight differences. Due to the careful design of the balance and associated system, buoyancy effects are less than the sensitivity at all pressures used. The capacity of the balance is one gram. Weight differences of 0.1 micrograms (less than three billionths of an ounce) can be reproducibly detected. Such sensitivity is necessary for a study of the infinitesimal quantities of surface impurities which markedly affect the properties of semiconductor devices. *Fig. 2* is a photograph of the quartz balance. A detailed discussion of the design of this type of balance may be found elsewhere. [6,9]

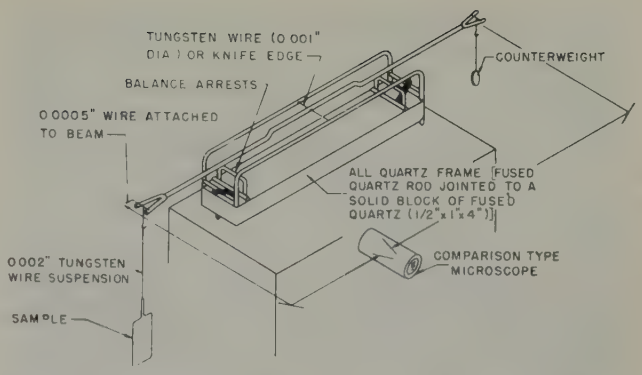
TUNGSTEN WIRE (0.001" DIA.) OR KNIFE EDGE
COUNTERWEIGHT
BALANCE ARRESTS
0.0005" WIRE ATTACHED TO BEAM
ALL QUARTZ FRAME FUSED QUARTZ ROD JOINTED TO A SOLID BLOCK OF FUSED QUARTZ (1/2"x1"x4")
0.002" TUNGSTEN WIRE SUSPENSION
COMPARISON TYPE MICROSCOPE
SAMPLE

Figure 1—Schematic Representation of Quartz Microbalance

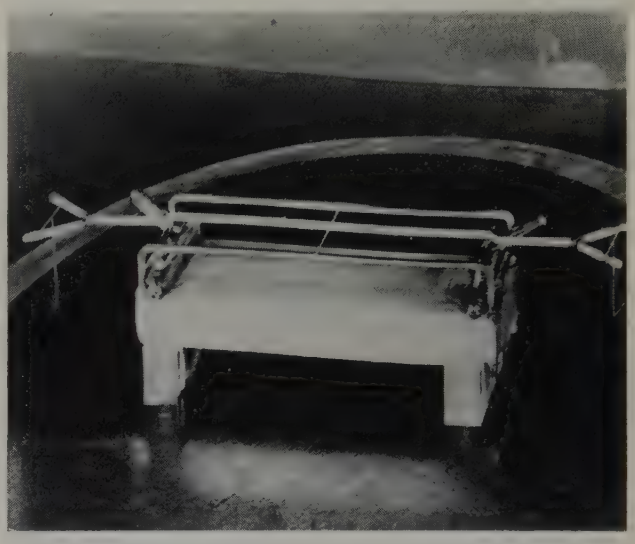

Figure 2—Quartz Microbalance

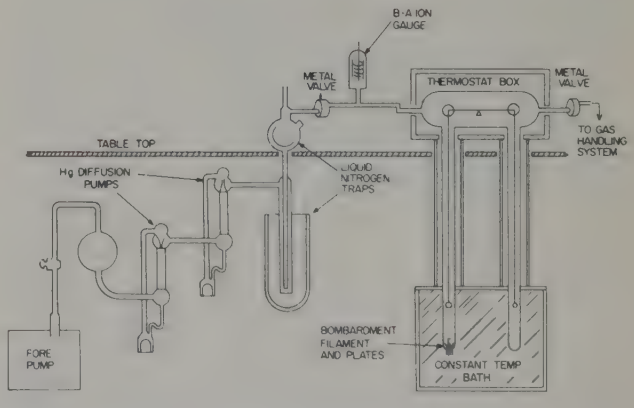

Figure 3—Schematic Representation of Vacuum Microbalance System

Vacuum System

The vacuum microbalance system is represented schematically in *Fig. 3*. The balance is enclosed in a Pyrex case which is connected through a double liquid nitrogen trap with two mercury diffusion pumps (Nottingham type) working in series. The balance case and hangdown tubes are thermostatted. After a bakeout of 12-36 hours, a vacuum of 5×10^{-10} *mm* is usually obtained as read on the Westinghouse WL5966 Bayard-Alpert ionization gauge. This gauge also serves as an ion-pump in the very low pressure region. Only metal valves capable of withstanding bakeout are used. No stopcocks or greased joints are allowable if the attainment of very low pressure is desired. The bakeout temperature is limited by the fused silver chloride which exhibits plastic flow at 300°C. Molybdenum and titanium getters are used to reduce further the partial pressure of oxygen. The concentration of oxygen, therefore, is usually less than one ten billionth of the total atmosphere in the system.

The sample is placed 22 inches below the balance beam by means of a 0.002 in. tungsten wire suspended from the beam-end cross wire. The specimen faces are parallel to the enclosing hangdown tube sides. The sample is heated with a small external heater which slides up around the hangdown tube. The quartz tubing in the sample region allows the use of temperatures of up to approximately 1200°C. The lowest temperatures at which measurements were made was —195°C (the boiling point of liquid nitrogen). This type of balance, however, has been used successfully even at liquid helium temperatures.[10]

The balance is connected to a gas handling system through a metal valve and a series of break-off tips. In this region, pumped by its own vacuum system, manometers, ion gauges, and calibrated volumes are available for the preparation of gas samples of known pressure. Although stopcocks are used here, the system is thoroughly outgassed prior to an experiment and the gases passed through two liquid nitrogen traps and a freshly flashed molybdenum getter, if desired, prior to admission to the sample area. Mass spectroscopic grade gases were used in all experiments. *Figs. 4, 5,* and *6* are photographs of the vacuum microbalance and gas handling systems and associated apparatus.

Sample Characteristics

Single crystal oriented samples are used in all experiments. The germanium and silicon samples are

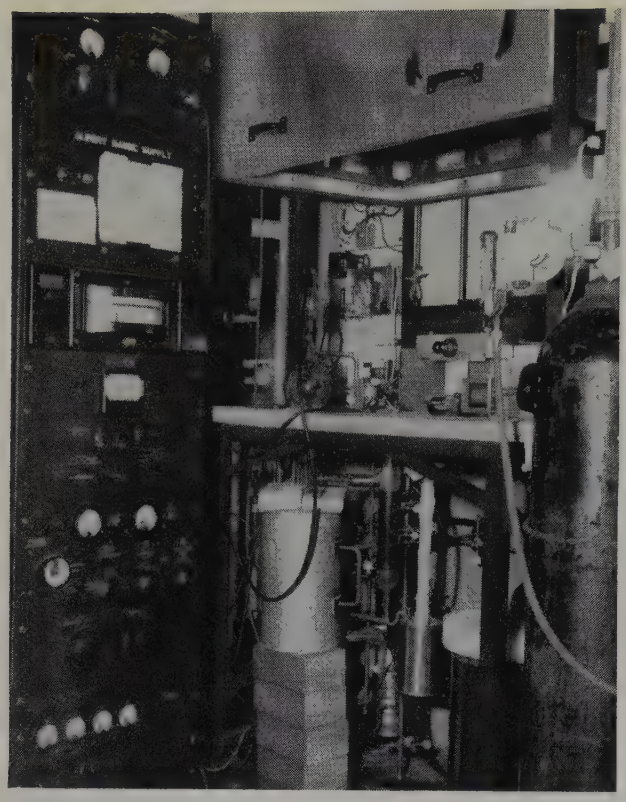

Figure 4—Vacuum Microbalance System

chemically etched with CP-4 to remove at least 0.005 in. from each face. The final sample plates are 0.002 to 0.004 in. thick and weigh approximately 0.3 grams. Geometric sample areas are 10-15 square centimeters. The actual surface area as determined by low temperature adsorption (—195°C) of krypton or nitrogen is about 1.5 to 2 times greater than the geometric area.

This is 10 to 100 times the area of a spherical counterbalance made of the same material as the sample plate and matched to within 10-100 μg of the weight of the plate. The counterbalance is held in a small platinum wire basket and suspended from the balance by means of a 0.002 in. tungsten wire.

Handling the Balance

The construction and handling of the balance requires a steady hand and considerable patience. The 0.0005 in. and 0.001 in. tungsten wires are sealed under tension to the balance by means of a small microtorch. Placing the sample on the balance requires extreme care for the slightest strain on the very fine cross wires may alter the sensitivity of the balance or even cause the wire to break. Breaking of any one wire requires removal of the balance from the system for repair. Since no stopcocks or ground joints are used, considerable glass blowing skill is required in assembling the system. For example, in sealing the sample into the system, the glass-to-glass seal of the hangdown tubes is made with the sample in position suspended from the balance by the fine tungsten wire.

Since in adsorption studies the observed weight change is obviously dependent upon the surface area of the sample, increased sensitivity, desirable in some instances, may be gained by use of powder samples. However, with powdered or crushed surfaces, an uncertainty concerning the orientation of the crystal faces is introduced. Active sites due to increased number of corners, edges, and damaged surfaces may also have a significant effect upon the experimental process.

Positive Ion and Electron Bombardment of Sample

Provisions were made for positive ion and electron bombardment of the sample. A tungsten filament and two molybdenum plates are mounted on a standard four-pin tube base sealed into the bottom of the sample hangdown tube. A metallic shield was placed above the filament to prevent evaporated tungsten from depositing on the sample. All metal parts were thoroughly outgassed prior to use. Mass spectroscopic argon was further purified as described above prior to being admitted to the microbalance system. The pressure prior to admitting the inert gas was usually 10^{-9} *mm* or less. All bombardments were at an argon pressure of 10^{-3} to 10^{-4} *mm*.

With the grid plates +275 volts, an ionizing electron current of 10-50 ma. was drawn by varying the emission of the filament. The ions formed were attracted to the sample on which potentials of up to 850 volts were placed through the balance ground connection. The balance beam was arrested during the experiments. The bombardments were at constant voltage and ion current conditions with the ion currents being adjusted by varying the filament emission.

Sputtering Experiments

In order to obtain a basic understanding of semiconductor surfaces, it is necessary that the surfaces studied be atomically clean. This requires that the surface have no residual oxide or adsorbed impurities. Such surfaces may be prepared by several different methods. In the cases of germanium and silicon the most widely used technique has been that of sputtering surface layers by positive ion bombardment using an inert gas such as argon. Most of the microbalance work has been with surfaces prepared in this manner.

While employing the vacuum microbalance to study the oxidation kinetics of clean germanium surfaces, it became apparent that the experimental method could be readily adapted to an investigation of the physical sputtering of solid surfaces by positive ions. Such an investigation[7] provided actual data as to the rate of removal of germanium during the ion-bombardment procedure used by most investigators to prepare clean surfaces. Oxidation data obtained with the sputtered surfaces provided additional information as to the cleanliness of the bombarded surfaces. Such information was very pertinent since there has existed a considerable controversy over the nature of the bombarded surface.

The positive ion bombardment of a solid surface results in the physical phenomenon of sputtering, i.e.,

removal of the material through collision with the bombarding ion. The use of direct weighing methods to determine rates of sputtering is not new; however, in general, other workers have not had sufficiently sensitive weight-determining methods or the extremely pure discharge conditions necessary for work in a low pressure gas discharge. Previous sputtering investigations have usually been in the range of at least several ma/cm^2 densities, whereas in this work the current densities were 1 to 12 $\mu a/cm^2$. The use of the microbalance in an ultra-pure environment revealed that, contrary to past evidence, efficient sputtering, i.e., one atom removed per impinging ion, could be obtained at low current densities.

The sputtering experiments were performed with the apparatus and method described above. 10^{16} to 10^{18} ions were involved in the bombardment process. The sample was baked at 450-600°C for up to one hour following the bombardment in order to anneal the atomically disturbed surface and to remove any gas which was adsorbed or trapped by the sample during the bombardment. Weight changes were recorded at various stages of the process.

In order to obtain significant results in a low pressure discharge, it is necessary to satisfy the following conditions. (1) The rate of ions striking the target surface must be greater than the rate of surface poisoning by adsorption of impurities from the environment. This condition was satisfied by our use of ultra-high vacuum and getter techniques. (2) The mean free path of the bombarding ions must be greater than the thickness of the positive ion sheath which forms around the sample so that energy is not lost by collisions in the sheath region. In our experiments the thickness of the ion sheath as calculated from the Langmuir-Childs space charge equation was always less than the mean free path.

Figure 7 is a plot of the rate of sputtering of Ge in μg/millicoulomb as a function of ion energy. The oxidized point shows the marked effect upon the rate produced by the existence of an oxide film on the sample surface. This illustrates the necessity for a high degree of cleanliness if accurate data is to be obtained and shows the importance of the nature of the target surface. Such metals as aluminum were originally thought not to sputter but with the removal of its strongly bound surface oxide, the rate of sputtering was observed to be comparable with other metals.[11] It is seen that the rate dropped rapidly in the region of 100 volts till at about 50 volts there was no measurable sputtering. The energy at which the sputtering process stops is called the threshold energy. The threshold value, being dependent upon surface condition, is not well defined. Atoms at corners, dislocations, and grain boundaries may be more weakly bound and consequently somewhat easier to remove. It has been found, however, that the threshold appears to follow an empirical law for normal ion incidence.[12]

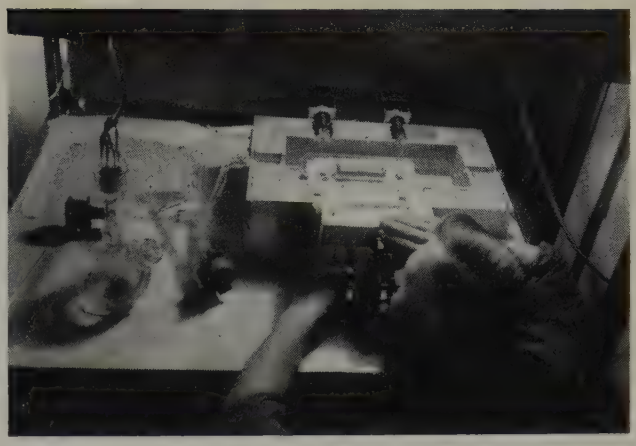

Figure 5—Vacuum Microbalance in Operation

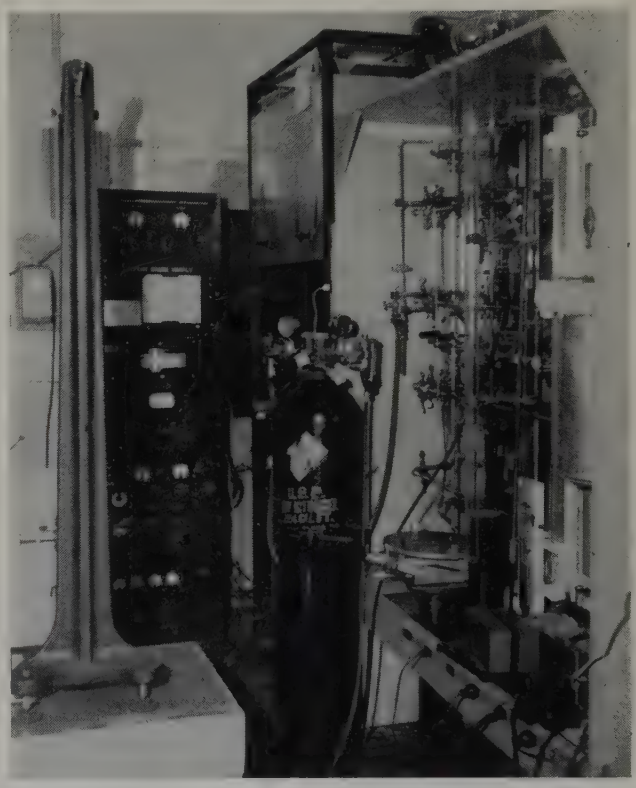

Figure 6—Gas Handling System and Associated Apparatus

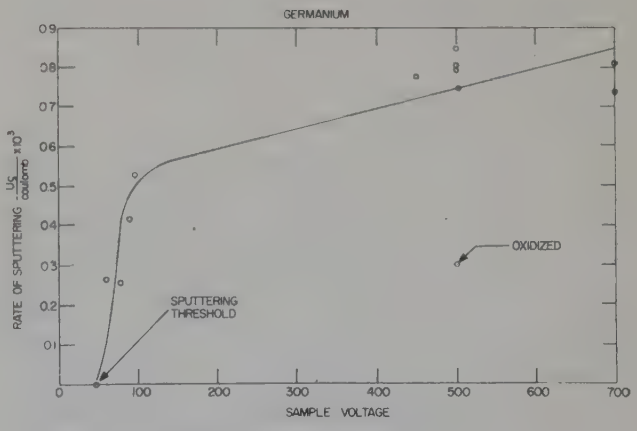

Figure 7—Rate of Sputtering in Germanium

$$V_0 = \left[\frac{1.7 \times 10^5 (M_g + M_n)\,\phi}{M_g^{\frac{1}{2}}\, M_n\, v_s}\right]^2$$

V_0 is the threshold energy M_g and M_n are the atomic weights of the ion and metal respectively, v_s is the bulk sound velocity of the metal, and ϕ is the heat of sublimation of the metal. That the threshold value is a function of angle of ion incidence and also follows a law in which the elastic constants are important, indicates that low energy sputtering occurs according to a momentum transfer process.

Low current density measurements are of value in understanding sputtering mechanisms. Because of the low density of ions arriving at the surface, it is very unlikely that more than one ion is involved in the removal of one atom. For example, at 5 $\mu a/cm^2$, each surface atom would receive an impact on the average of every 33 seconds. An efficiency of one for the bombardment process indicates that either almost every ion collision is successful in removing a surface atom or that more than one atom is removed per ion impact.

The ion bombardment technique also has certain practical applications. For example, knowledge of the rate of sputtering as a function of ion energy allows one to use the ion-bombardment as a micro-machining technique. The method is also generally used in semiconductor device fabrication for the removal of surface layers prior to the evaporation of doping materials onto the surface.

Oxidation Kinetics

Oxidation data obtained immediately following the bombardment provide additional information concerning the nature of the bombarded surface. Typical oxidation data at both 3 *mm* and 0.1 *mm* pressures for germanium and silicon surfaces is presented in *Fig. 8*. The kinetics are similar to those expected for monolayer adsorption, i.e., adsorption on a clean surface, with the total oxygen uptake consistent with the original surface being clean to some fraction of a monolayer of oxygen.

The oxidation kinetics of ion-bombarded germanium surfaces have been studied over an oxygen pressure range of 10^{-9} to 3 *mm*.[13,14] In general, at pressures above 0.1 *mm*, the process consists of an immediate oxygen uptake to form the first chemisorbed layer, followed by a slower process due to the formation of the second layer of oxygen, i.e., two oxygen atoms per surface atom. The second layer formation has been found to follow the logarithmic law

$$N = 1.4 \times 10^{14} \log_{10} t + 8.4 \times 10^{14}$$

at 0.1 *mm* pressure of oxygen and 25°C where N is the number of oxygen atoms adsorbed per square cm. of surface in t minutes of exposure to oxygen. This general behavior has been observed by the author[14] and others,[15,16] at oxygen pressures up to 75 *mm*. It has been shown elsewhere[17] that such a logarithmic rate law, generally referred to as an Elovich type, can be used to describe the interaction of a gas and a solid surface for many different systems.

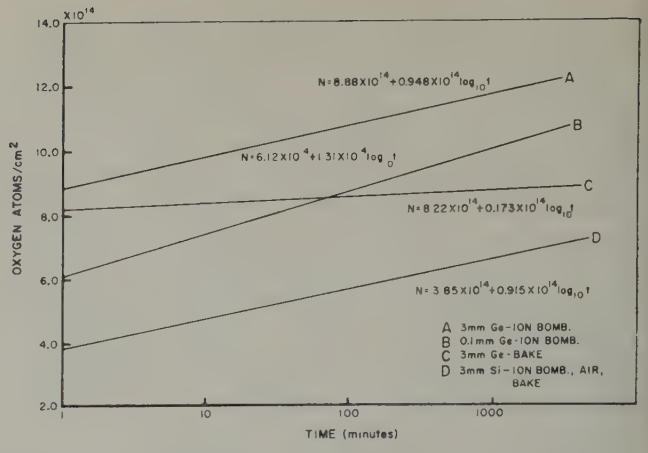

Figure 8—Oxidation of Germanium and Silicon

At pressures of about 10^{-9} *mm*, the adsorption of the first layer of oxygen on germanium is so slow that the kinetics of the process can be observed. From such data,[14] it has been found that the sticking coefficients (S) of oxygen on germanium, i.e., that fraction of the total number of atoms striking a surface which are adsorbed by the surface is of the order of 10^{-3} at a coverage of 0.1 monolayer decreasing to less than 10^{-4} at monolayer coverage of oxygen. Other workers using electron diffraction techniques for studying germanium surfaces have reported similar values for S. That S for oxygen on germanium is so low (S = 0.5 for nitrogen on tungsten) has been used by some[18] to support the contention that ion-bombarded surfaces are not atomically clean.

Preliminary experiments with silicon show the kinetics of chemisorption of the second layer of oxygen to be very similar to those for germanium.[14,19] No value for the sticking coefficient has yet been published.

Providing Clean Surfaces

One of the most interesting aspects of the surface effort has concerned the attempts to provide clean, reproducible germanium surfaces. The conventional technique of prolonged bakeout at or near the melting point of the material was not satisfactory. Surfaces prepared by crushing in vacuum, or by reduction in H_2[16] or CO[15] have been used; however, as mentioned earlier, the most popular and widely discussed method has been that of positive ion bombardment. The extent of cleanliness of such surfaces, however, has been the cause of considerable discussion.

Early surface investigators[20,21] reported that ion-bombarded surfaces which had been exposed to oxygen could be restored to their pre-oxygenated (clean) condition by a brief heating at 500°C. Since it is to be expected that the first chemisorbed layer of oxygen could not be so readily removed, speculation arose as to the possible causes of this thermal regeneration phenomenon. The explanations offered were: (1) The surfaces were not originally clean to less than

a monolayer. Consequently, the absorbed oxygen was very weakly bonded and therefore easily removed. (2) The oxygen dissolved in the germanium on heating. Such behavior has been observed in other metal oxygen systems. (3) The oxygen is removed as GeO, which is quite volatile at 500°C. Recent work with the microbalance[22] and in other laboratories[23] indicates that the vaporization of GeO is probably the significant factor; however, a temperature of 575°-600°C is necessary for complete regeneration. This, therefore, still leaves unexplained the numerous observations at 500°C and a reported regeneration at a temperature as low as 300°C. It must be considered, however, that such observations were usually indirect in that an electrical property such as the surface conductivity was being measured. The sensitivity of such measurements may well be much greater than that of the available adsorption techniques. The regeneration effect still remains one of the very interesting and little understood factors concerning germanium surface behavior.

Applications

The results of the chemical surface studies of germanium and silicon surfaces have contributed substantially to device performance. It is now possible to understand changes in device parameters on exposure to such ambients as oxygen and water. The recently reported stabilization of device properties by controlled thermal growth of oxide films on silicon[24] is an excellent illustration of the contributions of the intensive surface effort of the past several years.

As a further illustration of the usefulness of the microbalance equipment, it is worthwhile discussing briefly the presence of such impurities as oxygen in germanium crystals. During initial microbalance experiments with germanium, large pressure rises with corresponding weight losses were observed as the samples were heated.[3] It was not possible to correlate these weight changes with the desorption of adsorbed gaseous impurities, or the vaporization of germanium or one of its oxides. Separate mass spectographic investigations[25] substantiated our belief that the observed changes were due to the evolution of oxygen, nitrogen, and hydrogen from the bulk material. It was only through the continuous experimental record provided by the microbalance, however, that we were able to detect the presence of these elements.

Role of Microbalance in Future Research

The increasing interest in high temperature semiconductor devices has stimulated research on new materials. Silicon carbide has advanced to the front for high temperature applications. The design of the vacuum microbalance system makes it possible to study such materials at temperatures in excess of 1200°C. The behavior of silicon carbide and other such materials in oxygen and other ambients are problems which will soon be of importance. The versatile microbalance equipment will fit easily into the basic research effort on high temperature materials.

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The Growing Role of Graphite In The Semiconductor Processing Industry

W. E. ALLSOPP*

[Tear sheets of this article are available on written request]

THERE IS A WIDEBPREAD, growing awareness, in the semiconductor industry, that the role of graphite is increasing in scope. The many interesting properties of graphite are finding new applications in semiconductor processing—many not yet generally realized.

For instance, we find graphite being put to use in crystal-pulling operations . . . as a resistance element in high temperature furnaces . . . as susceptor rings . . . and other similar applications. Again, as we review fundamental purification methods for germanium and silicon, we find graphite being used extensively in the manufacture of reduction and zone refining boats. Further along in the processing of semiconductor devices, graphite is again used in alloying boats or jigs during the actual fusion process that occurs when a semiconductor device is fabricated. Toward the final processing of a transistor or rectifier, graphite finds further use in the fabrication of the header jig or fixture. Other uses, of lesser importance, also occur in many semiconductor processing and production lines.

All this is not without good and sound technical reason. The growing role that graphite is playing springs from its particular physical and chemical properties—properties that make it an extremely versatile, unique and valuable material for the semiconductor processing industry. Yet, even under these attention-commanding conditions, much too little importance is being paid the actual grades and the properties of these various grades. Additionally, in the stress of achieving pressing production goals, far too little attention is being directed to the actual specifications and performance of the various types of graphite as they relate to the final performance of the finished transistor. This lack of critical appraisal is probably the highest tribute that could be paid to the material itself . . . for, it has worked, and is working, in all kinds of applications regardless of the small amount of attention given to it.

Even so, it is inevitable that problems arise when adequate attention is not given to this material. Many of these problems can be quickly solved for the operating engineer in semiconductor manufacturing, by a clearer understanding of some of the properties of graphite. As a first step in the overall picture, it would be advantageous to differentiate between carbon and graphite. Chemically, of course, carbon and graphite are identical. Carbon occurs in nature in three general forms: coal (amorphous, as a mixture of hydrocarbons); diamond (crystal); and graphite (crystal). Now, graphite occurs naturally in a hexagonal molecular crystal orientation, while carbon diamond occurs in a cubic molecular crystal orientation. These are natural states.

The method of producing graphite artificially, was developed in about 1896 by Acheson. So basic was the original method that it is still used today with only minor refinements.

Artificial graphite is synthesized by bonding with a mixture of petroleum coke, granular anthracite mixed with various blends of lamp black and coal tar pitch, all heated electrically by passing an extremely high current through it for a good many hours. At this stage the pre-crystallization from amorphous to graphitic carbon occurs. When the temperature of this reaction mixture is kept below approximately 1800°C, the result is amorphous carbon. If the temperature is increased appreciably above 1800°C, the result is graphite.

Physically, these forms of carbon are very different indeed. Amorphous carbon, or carbon as it is referred to hereafter, is extremely brittle, decidedly

Fig. 1—Sharp tool used with an old type of extruded graphite.

*Technical Director and Assistant To The President
United Carbon Products Company

abrasive, and definitely hard. Specifically, the Shore Scleroscopy Hardness of carbon may run from 70 to 90. Further, its specific electrical resistance is approximately .002 ohms per inch cubed and it has a thermal conductivity of only 10% to 20% that of graphite.

These characteristics are quite different, indeed, from graphite. For instance, various grades of graphite run a Shore Scleroscope Hardness of from 50 to 25 with a specific electrical resistance, approximately, of from .0002 to .0005. Some of the many interesting characteristics of graphite that are of vital interest to the semiconductor industry are:

- ....graphite, unlike carbon, is not hard and brittle, but a much softer material.
- ....graphite is much less abrasive than carbon and generally speaking, less porous.
- ....graphite is extremely resistant to thermal shock—it can be heated to a white hot temperature and immediately dropped in cold water without fracturing. This process can be repeated indefinitely without fracturing.
- ....graphite does not become deformed, nor appreciably lose its strength, at high temperatures.
- ....graphite will not "wet" on contact with most molten metals.
- ....graphite has the ability to withstand temperatures well above the melting point of most metals.

All of these factors point up the many advantages of graphite as an ideal material for use as crucibles and containers for high purity metals. Additionally, resistance heaters made of graphite can be made rigid and will not lose their strength or be appreciably deformed at high temperatures. Of extreme importance to the semiconductor industry is graphite's ability to be economically purified to near ultimate purity.

The incessant, continuous drive in the semiconductor industry for improved production efficiency focuses attention on the purity of graphite used in processing. It is of paramount importance because of the well known fact that the contaminations of high purity germanium or silicon, by even parts per billion of certain elements, will materially affect the performance of the final semiconductor device. For this reason, the selection of only the purest graphites for use in semiconductor production is the mark of a wise and efficient semiconductor engineer.

While there are several ways of purifying graphite, the most successful entails the utilization of the now famous "F" process. This process, originally developed by the United Carbon Products Company to produce graphite used in nuclear reactors, is used when it is imperative to have graphite that is as close to ultimate purity as can be obtained. The "F" process results in graphite having a maximum total ash content that will not, in general, exceed an average of ten to twenty parts per million and will have present no detectable boron—even when the material is analyzed by the most sensitive spectrographic analytical methods. Because of classification restrictions, few details concerning this process can be discussed. In general however, it consists of the treatment of graphite at high temperatures in the neighborhood of 3000°C, under closely controlled reactive atmospheres. The end result is extremely important to the semiconductor industry—this "F" process ultra pure graphite protects the semiconductor manufacturer from the contamination of expensive hyper-pure germanium and silicon.

In still another important way, ultra pure graphite can improve any semiconductor productive efficiency, for it is a matter of record that the oxidation rate of ultra-pure graphite is much lower than commercial grade graphite. Since most of the graphite parts used in semiconductor applications are subjected to high temperatures, the life-span of the part is generally related to the oxidation of the graphite part itself while it is being removed from the hot furnace into air. The oxidation rate of graphite has a direct relationship to the impurities in it. For example, as little as twenty to forty parts per million of either sodium, potassium, vanadium or copper in graphite will increase the rate of oxidation by a factor of 6 at 550° C . . . this means a reduction in the time for a 5% oxidation of the graphite part from 200 to 120 hours. Indeed, in any

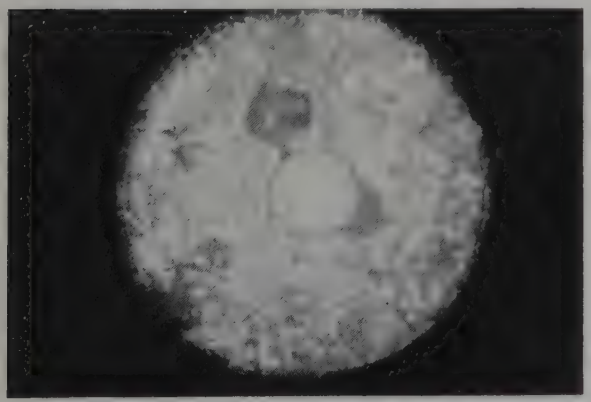

Fig. 2—Dull tool used with molded UT-2-S graphite.

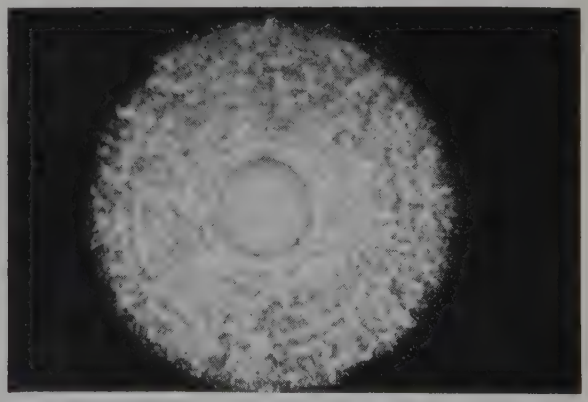

Fig. 3—Sharp new tool used with molded UT-2-S graphite.

consideration of efficient production, this oxidation factor alone indicates that the highest purity graphite obtainable seems quite necessary.

In addition to the considerations of freedom from contamination and a low oxidation rate, semiconductor producers should give thought to the machinability of the graphite parts they use. To work properly, graphite for semiconductor fusion and alloying boats must be capable of being machined to high tolerances with good surfaces. To achieve this, the graphite should be selected with reference to a non-porous, non-abrasive structure.

In the past, only extruded graphite was available for the fabrication of semiconductor parts. Because of the porosity of this extruded material, it precluded the possibility of close tolerances (±.0002″) because of pore size interference. There must be no pore size interference that keeps machined surfaces from being smooth or does not permit maximum sharpness of corners . . . this would effect the geometry of the machined cavities and consequently the performance of the finished semiconductor device. Today there is a selection of molded, low-porosity graphite available in ultra pure grade, which is tailored for semiconductor industry use.

An additional factor in achieving smooth surfaces and sharp corners is the necessity of selecting a graphite that minimizes tool wear. The type of super-sharp corners and smooth surfaces needed in semiconductor processing cannot be produced with dull tools. Let us not forget, also, that economy-priced graphite parts cannot be produced if tools must be sharpened or rebuilt in excess. In some past instances of alloying boat production, the tool needed to be rebuilt after each cavity—certainly not conducive to economy. To illustrate the importance of this point, the photomacrographs shown in *Figs. 1, 2* and *3,* illustrate how very necessary it is to use sharp tools.

These photomacrographs point up several interesting observations. In *Fig. 1,* it will be noted that the old extruded type graphite does not give an ideal surface finish or sharp corner detail as does the newer molded graphite cut with similar quality tools. However, as *Fig. 2* illustrates, even though an ideal graphite is used, a satisfactory end product cannot be achieved with a dull tool. The ideal situation is shown in *Fig. 3,* where a sharp, new tool is used on a molded UT-2-S graphite. This is the characteristic which is desired for all graphite parts used in this critical phase of semiconductor production. It should be noted that the cavities illustrated are "idealized" and in no way conform to any transistor manufacturer's actual cavities.

Table I indicates the characteristics of United Carbon Products Company graphite used in the manufacture of fusion boats.

TABLE I

Fusion Boat Graphite Evaluation Chart

Graphite Grade	Scleroscope Hardness	Relative Porosity	Use When
UT-1	54 Average	Fair	Hardness is primary requisite
UT-2	38 Average	Good	Hardness plus fairly high machine tolerances
UT-2-S	27 Average	Very Good	Machine tolerances primary requisite

Although molded graphite is limited in size, the extruded grade is available and used for the large zone refining boats. Also, it is used for large parts that exceed 6 inches in diameter and 12 inches in length, or exceed the size of parts that can be fabricated from plates 2-1/2″ x 12″ x 12″. However, these qualifications are not as serious as they might first seem, since most large parts have relaxed tolerances with regard to both porosity and machined surface requirements, as long as high purity is maintained.

In brief summary, the role of ultra pure graphite in the semiconductor industry is growing with improved technology. Efficient, low-cost semiconductor production demands the selection of proper graphite parts. In general, the unique properties of graphite are finding increased usages on semiconductor production lines. Ultra pure graphite, in particular, is being demanded to achieve a contamination-free product combined with a low oxidation rate for utmost economy. The consideration of smooth surfaces and sharp corners to give optimum semiconductor production hinges on the physical characteristics of the particular graphite and the quality of the tools used. In essence, the selection of the proper grades of graphite to be used demands the same critical considerations as the germanium or silicon used for the device itself.

APPLICATIONS ENGINEERING DIGESTS

For further information circle the number of the desired application note on the inquiry card provided at the back of the magazine.

APPLICATIONS ENGINEERING DIGEST No. 4

Series connected D.C. to A.C. Converter, Delco Radio Division, G. M. Corp., Kokomo, Indiana.

The factor which limits the *d*-c supply voltage to a transistorized power converter is the maximum voltage which may be applied between the emitter and the collector of the transistor. The circuit shown in *Fig. 1* indicates how converter circuits may be connected in series to allow the operation of converters at higher supply voltages than are otherwise possible.

In order to maintain proper phasing and equal power distribution, it is necessary that all of the transformer windings be on the same core. With such an arrangement the voltages applied to each transistor will be equal and inversely proportional to the number of pairs of transistors which are in the circuit. Maximum efficiency of operation will be achieved by using a core material whose hysteresis loop is as nearly rectangular as possible.

The four transistors operate as switches which are controlled by the bias voltages which are in turn induced in the feedback windings of the transformer and applied to the transistor bases. Without any voltage being induced in the feedback windings, the resistors R_1, R_2, R_3, and R_4 function as a voltage divider network which maintains sufficient forward bias on the transistor bases to assure reliable starting of oscillation.

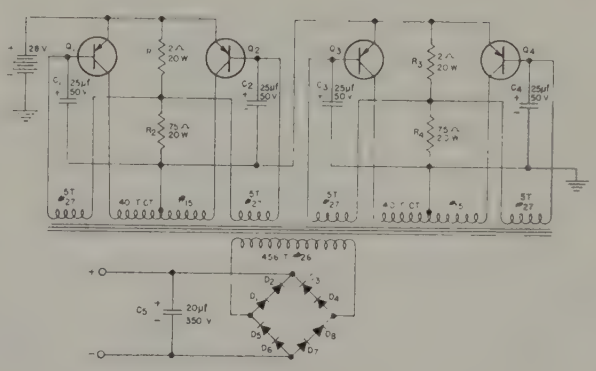

Fig. 1— Schematic of series connected converter circuits.

The left hand transistors of each pair conduct simultaneously in series as the right hand transistors are cut off, and vice versa. For purposes of analysis, assume that Q_1 and Q_3 are conducting (junctions saturated), and Q_2 and Q_4 are cut off. The supply voltage is thus applied to the left hand half of each of the primary windings of the transformer.

When Q_1 and Q_3 start to conduct, the current through the left hand halves of the primary windings increases rapidly in all windings of the transformer. As soon as the core of the transformer is saturated, the induced voltages decrease to zero because the rate of flux change is practically zero.

As the voltage induced in the feedback windings (and applied to the transistor bases) decreases, Q_1 and Q_3 are no longer saturated and their collector currents (flowing through the left hand halves of the transformer primaries) decrease until the core is no longer saturated. This causes the core flux to decrease, inducing voltage in all of the transformer windings of a polarity which is opposite to that induced when Q_1 and Q_3 began to conduct. The voltage thus induced in the feedback winding biases Q_1 and Q_3 to cutoff at the same time it drives Q_2 and Q_4 to saturation, allowing current to flow through the right hand halves of the primary windings. This current flow creates a core flux of a polarity which is opposite to that which exists when Q_1 and Q_3 are conducting and induces a voltage in the secondary of the transformer of a polarity opposite to that induced when Q_1 and Q_3 are conducting.

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APPLICATIONS ENGINEERING DIGEST No. 5

High Input Impedance Amplifier Using Silicon Transistors, Texas Instruments, Inc., Dallas, Texas (Arthur D. Evans)

A transistor amplifier is usually considered to have relatively low input impedance, high output impedance, and high voltage gain. Since the maximum available power gain of the device is limited, voltage gain must be decreased if it is desired to have high input impedance and low output impedance. By employing negative feedback, voltage gain can be "exchanged" for input impedance. The referenced report describes a transistor amplifier having input impedance of 8 megohms, a voltage gain of 40 *db* and an output impedance of 600 ohms. The gain is stable to ±0.10 *db* over the temperature range of −55°C to +125°C, and to within ±1 *db* over the frequency range 6 *cps* to 300 *kc*. The input impedance is greater then 1 megohm betwen the

frequencies of 25 *cps* and 350 *kc*, and greater then 8 megohms between the frequencies of 400 *cps* and 30 *kc*.

The complete amplifier circuit is shown in *Fig. 1*. The four stages are direct-coupled. Adequate stability of bias conditions is provided by means of the large emitter resistors *R4, R9* and *R14*, which are by-passed for signal frequencies. Bias voltage for the first stage is developed across the 9-volt "Zener" diode, *D1*. The collector of *Q1* is coupled to the feedback resistor R_{F1} by *C2* and *D1*. If this collector were by-passed to ground, the input impedance would be shunted by the h_{ob} of this unit. The following table gives the approximate *d-c* bias conditions of the four transistors:

TRANSISTOR	V_{CE} volts	I_E ma
Q1	3	0.010
Q2	6	0.50
Q3	13	0.59
Q4	6	4.8

The output impedance is set by the value of *R12* which is 600 ohms. The input impedance is approximately equal to the product of the amplifier current gain and the feedback resistor *R13*. Since the current gain is a function of transistor parameters, the input impedance can be expected to be a function of ambient temperature.

The voltage gain is largely determined by the ratio of the output resistor *R12* to the feedback resistor *R13* and is almost independent of transistor parameters. It, therefore, should not be sensitive to ambient temperature variations. This is confirmed by *Fig. 2*, which is a plot of the voltage gain *vs* ambient temperature. The noise level of the amplifier will be a function of the input termination. Equivalent input noise will range from about 24 μvolts with the input shorted up to about 540 μvolts with the input open. Careful consideration should be given to the layout of the amplifier, particularly with respect to stray capacity to ground. In the breadboard model constructed for test purposes, all components were mounted on a 2" x 4" sheet of aluminum which was insulated from the main chassis and electrically connected to the ungrounded side of feedback resistor *R13*. This greatly improved the high frequency characteristics of the amplifier by reducing the effect of stray capacity between the components and ground.

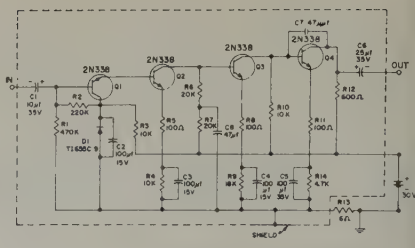

Fig. 1— Circuit of Amplifier

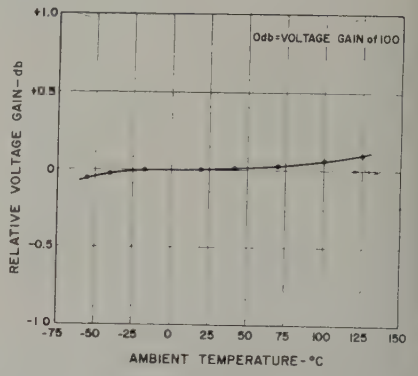

Fig. 2— Relative Gain vs Ambient Temperature

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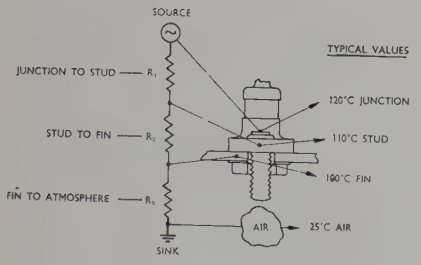

Fig. 1— Ohms Law analogy of rectifier/fin/air system.

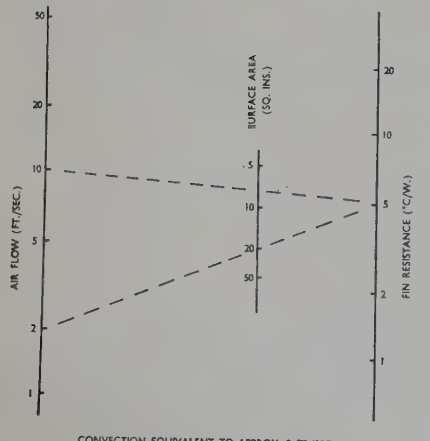

Fig. 2— Surface area/air flow nomograph.

Cooling of Silicon Power Rectifiers, Ferranti Ltd., Gem Mill, Chadderton, Oldham, Lancs., England.

The rating of silicon junction power diodes is closely related to the junction temperature and the most commonly used and simplest method of cooling makes use of the surrounding air. The addition of extra surface area to the diodes enables the heat generated to be carried away from the diode and attached heat sink by convection in the surrounding air.

Materials with high thermal conductivity such as copper or aluminum are the most suitable materials for heat sinks. It is undesirable to use materials which have a contact potential significantly different from copper as there is a possibility of corrosion developing between the stud and heat sink.

Figure 1 shows how the rectifier/fin/air system may be presented using a thermal "Ohms Law" analogy. The flow of heat (watts) through the various thermal resistances (R_1, R_2, R_3) between the source (silicon junction) and ground (atmosphere) produces a temperature drop proportional to the resistance values.

An estimation of the maximum thermal resistance permissible for satisfactory operation of a diode may be determined from the equation:

$$R_3 = \left(\frac{T_2 - T_1}{W} \right) - R_2$$

where R_3 = Thermal resistance of fin unit (°C/W)
R_2 = Thermal resistance between stud mounting and fin surface (°C/W)
T_2 = Maximum permissable stud temperature (°C)
T_1 = Ambient Air Temperature (°C)
W = The rated dissipation of the diode (watts)

Having estimated the heat sink thermal resistance from the equation given above, reference to *Fig. 2* will provide an assessment of the necessary surface area/air flow relationship.

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Designing Transistor Circuits, Part I	Electronic Equip. Engineering Dec., 1958	Short term storage of information is obtained by bistable multivibrator flip-flops.	R. B. Hurley
On The Theory of Field Emission From Semiconductors	Electronic Exp. 10/58 Complete trans. from Radiotek. i Elek. 7/58	A refinement of the theory of field emission and thermionic emission from semiconductors.	G. F. Vasil'ev
Tellurium Oxide Photoresistors	Electronic Exp. 10/58 Summary trans. from Zhur. Tekh. 6/58	Method for preparing photosensitive layers of TeO_2 by sublimating tellurium oxide in a vacuum.	R. LaBerlaga S. N. Chechurin
The Kinetics of Phototriodes	Electronic Exp. 10/58 Excerpt trans. from Zhur. Tekh. 6/58	Qualitative discussion concerning the mechanism of phototriodes and the shape of relaxation curves pertaining thereto.	S. M. Ryvkin N. B. Strokan
Silicon Photodiodes	Electronic Exp. 10/58 Summary trans. from Zhur. Tekh. 6/58	Results obtained from studying the use of silicon photoelements for converting light into electricity when operating in a photodiode mode.	N. B. Strokan V. M. Tuchkevich V. E. Chelnokov
On the Electron-Hole Transition in Point-Contact Solid Rectifiers	Electronic Exp. 12/58 Complete trans. from Dok. Okad. Nauk 8/58	Experiments have verified the formation of a region of *p*-type conduction at the point contact of a diode due to the effect of an electric pulse on *n*-type Ge or Si.	V. G. Mel'nik S. S. Gutin I. G. Mel'nik
On Using Cyclotron Resonance in Semiconductors for Amplification and Generation of UHF Oscillations	Electronic Exp. 12/58 Complete Trans. from Zhur. Eksper-i-Teoret. 9/58	Cyclotron resonance in semiconductors can be used for designing regenerative amplifiers or oscillators at UHF.	A. S. Tager A. D. Gladun
Oscillogramming the Electromagnetic Torque of *AC* Machines Using Film Hall EMF Pick-up Units	Electronic Exp. Complete trans. from Zhur. Tekh. 9/59	Generalization of method for *a-c* machines described.	D. D. Elpat'evskaia I. A. Matus V. A. Perchuk
Zener Diodes Stabilize Tube Heater Voltages	Electronic Industries 12/58	Article discusses regulation of *d-c* and *a-c*- heater voltages. Circuits and curves are given.	P. L. Toback
Low Frequencies Vary T- Parameters	Electronic Industries 12/58	Data reveals that the magnitude of equivalent T-parameters changes radically at low frequencies.	G. N. Kambouris
Sweep Equipment Displays Transistor Beta	Electronics 12/5/58	Falloff in beta with increasing collector current is displayed on an auxiliary scope over 0-200 *ma* range.	R. Zuleeg J. Lindmayer
Transistor Switch Design	Electronics 12/5/58	Four parameters tabulated for eight types permits designer to match transistor pairs for optimum operating characteristics.	Arthur Gill

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Graphical Designing of Transistor Oscillators	Electronics 12/5/58	New method based on Barkhausen's criteria for oscillation is used with graphic technique to design stable transistor crystal oscillator.	W. R. McSpadden
Semiconductors Cool and Control Density Gage	Electronics 12/5/58	Gage makes use of Peltier effect by using semiconductor thermoelements to maintain uniform cooling temperatures.	C. W. Hargens
Bistable Circuits Using Unijunction Transistors	Electronics 12/19/58	Modified circuit has clamping diode that holds emitter votage below peak-point voltage.	T. P. Sylvan
Present Status of Precise Information on the Universal Physical Constant	IRE Trans. on Instrumentation 12/58	Has the time arrived for their adoption to replace our present arbitrary conventional standards?	J. W. DuMond
Calculations on the Shape and Extent of Space Charge Regions in Semiconductor Surfaces	Jl. Appl. Phys. 12/58	The shape and extent of space charge regions in semiconductor surfaces are briefly discussed.	G. C. Dousmanis R. C. Duncan
Production of Dislocations in Germanium by Thermal Shock	Jl. Appl. Phys. 12/58	Dislocations introduced into single crystals grown by the Czochralski technique have been studied.	R. S. Wagner
Electrophotoluminescent Amplification	Jl. Appl. Phys. 12/58	Alternating electric fields can modify the time distribution of luminescent recombination in sulfide-type phosphors.	R. E. Halstead
Photoconductive Response of Single Crystal Germanium Layers Prepared by the Pyrolytic Decomposition of GeI_2	Jl. Appl. Phys. 12/58	Layers of single crystal Ge have been prepared by pyrolytic decomposition of GeI_2 at about 350°C upon single crystal seeds of Ge. The photoresponse of such layers at 77°K was found to extend to about 6 μ.	D. C. Cronemeyer
Radiation-Induced Recombination Centers in Germanium	Jl. Appl. Phys. 12/58	An attempt has been made to provide a better understanding of minority carrier recombination processes in irradiated Ge.	O. L. Curtis Jr. J. W. Cleland J. H. Crawford Jr.
Theoretical Surface Conductivity Changes and Space Charge in Germanium and Silicon	Jl. Appl. Phys. 12/58	Graphs display predicted surface conductivity changes as a function of resistivity for various values of surface potential.	V. O. Mowery
Grain Boundary Photodector	Jl. Appl. Phys. 12/58	(Letter to Ed) A system which makes use of the photoresponse of grain boundary capacitors to measure radiation to about 1.8 microns wavelength.	W. W. Lindemann R. K. Mueller
Diffusion Control in Silicon by Carrier Gas Composition	Jl. Electrochem. Soc. 12/58	A single heating process is described for producing controlled *p-n* and *n-p-n* diffused structures in silicon.	C. J. Frosch L. Derick
Diffusion into Silicon from Glassy Layers	Jl. Electrochem. Soc. 12/58	The diffusion of boron into silicon from glassy layers containing the system $K_2O — SiO_2 — B_2O_3$ was investigated.	J. E. Cline R. G. Seed
Diffusion Concentration Profiles by Analog Computation	Jl. Electrochem. Soc. 12/58	Simulation of diffusion processes on an analog computer permits solutions to the diffusion equation.	W. Waring
A Sensitive Method for Measuring Optical Scattering in Silicon	Jl. Electrochem. Soc. 12/58	An instrument has been developed for the observation of optical scattering in silicon and in intermetallic compounds.	G. H. Schwuttke O. A. Weinreich P. H. Keck
Effects of Certain Chemical Treatments and Ambient Atmospheres on Surface Properties of Silicon	Jl. Electrochem. Soc. 12/58	Measurements of surface conductance, recombination velocity (S), and field effect were made on *n*- and *p*-type silicon specimens.	T. M. Buck F. S. McKim
Saturation Currents in Germanium and Silicon Electrodes	Jl. Electrochem. Soc. 12/58	Germanium electrodes in KOH and silicon electrodes in dilute HF solutions have been studied to the sources of carrier regeneration.	J. B. Flynn
High-Pressure, High-Temperature Growth of Cadmium Sulfide Crystals	Jl. Electrochem. Soc. 12/58	A process is described for growing cadmium sulfide crystals of uniform size, shape, and homogeneity from the melt.	W. E. Medcalf R. H. Fahrig
Some Semiconducting Properties of HgTe	Jl. Electrochem. Soc. 12/58	Mercuric telluride was synthesized and single crystals were prepared both in a horizontal capsule and by the Bridgman Technique.	J. Black S. M. Ku H. T. Minden
Electron Mobility in InP	Jl. Electrochem. Soc. 12/58	The Hall mobility of electrons in InP has been observed as a function of temperature and of carrier concentration.	M. Glicksman K. Weiser

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Preparation and Some Characteristics of Single-Crystal Indium Phosphide	Jl. Electrochem. Soc. 12/58	A technique for purifying P, reacting In and P, purifying InP by directional crystalization and growing large crystals is described.	T. C. Harman J. I. Genco W. P. Allred H. L. Goering
Preparation of Crystals of Pure Hexagonal SiC	Jl. Electrochem. Soc. 12/58	The mode of growth of SiC crystals in laboratory furnaces is examined. The means of producing pure crystals are discussed.	D. R. Hamilton
Use of Bismuth as a Donor-Type Impurity in Germanium Single Crystals	Jl. Electrochem. Soc. 12/58	Results indicate no major diffculties inherent in the use of Bi as a satisfactory doping impurity for Ge.	G. Mortimer
Properties of Some Germanium Single Crystals Grown from Solutions of Molten Metals	Jl. Electrochem. Soc. 12/58	Report of an attempt to obtain single-crystal material grown under equilibrium conditions, which material would be similar to that produced by an alloy fusion technique.	H. F. John
Semiconducting Compounds—A Challenge in Applied and Basic Research	Jl. Electrochem. Soc. 12/58	The implications of recent investigations as regards band structures, state densities, charge carrier mobilities, crystal imperfections, and other basic characteristics are discussed.	A. C. Beer
Measurement of Lifetime by the Photoconductive Decay Method	Jl. of Electronics and Control (Brit) 12/58	General equations have been derived for the decay of photo-injected carriers in a semiconductor with time.	B. K. Ridley
On the Lifetime and Diffusion Constant of the Injected Carriers and the Emitter Efficiency of a Junction Transistor	Jl. of Electronics and Control (Brit) 12/58	It is found that for a given temperature the effective lifetime passes through a maximum as the bias current is increased from a low value.	S. Deb A. N. Dow
Decay of Excess Carriers in Semiconductors	Phys. Rev. 12/1/58	Discussion of the nonlinear differential equations which govern the decay of excess carriers with arbitrary densities.	K. C. Nomura J. S. Blakemore
Mechanism of the Formation of Donor States in Heat-Treated Silicon	Phys. Rev. 12/1/58	A mechanism for the donor formation during heat treatment of silicon crystals is presented.	W. Kaiser H. L. Frisch H. Reiss
Piezoresistance in N-Type GaAs	Phys. Rev. 12/1/58	Piezoresistance and elastoresistance coefficients of *n*-type GaAs were determined at room temperature.	A. Sagar
New Germanium Isotope Ge^{65}	Phys. Rev. 12/15/58	A new germanium isotope has been produced by the $(a,3n)$ reaction on Zn^{64}.	N. T. Porile
Thermoelectric Power and Electron Scattering in Metal Alloys	Phys. Rev. 12/15/58	A phenomenological theory of thermoelectric power in binary, ternary, and more complex noble-metal base alloys is presented.	C. A. Domenicali
A Transistor-Magnetic Core Counter (Correspondence)	Proc. IRE 12/58	Purpose of letter is to describe a simple device useful at counting rates as high as $2X10^6$ pulses/sec.	H. R. Irons
The Internal Current Gain of Drift Transistors (Correspondence)	Proc. IRE 12/58	Purpose of note is to show that a complete specification of the internal current gain of a drift transistor can be obtained using a relatively simple method.	F. J. Hyde
The Dependence of Minority Carrier Lifetime on Majority Carrier Density (Correspondence)	Proc. IRE 12/58	Note discusses condition under which the ratio of the diffusion length of holes in an *n* region to that of electrons in an adjacent *p* region and the ratio of the conductivities of the region follow a simple relationship.	D. M. Evans
Current Build-up in Semiconductor Devices (Correspondence)	Proc. IRE 12/58	Purpose of letter is to lay a mathematical foundation for the switching action of devices in which carrier multiplication at a collector junction plays an important role in the switching process.	W. Shockley J. Gibbons
Theory of the P-N Junction Device Using Avalanche Multiplication (Correspondence)	Proc. IRE 12/58	Note proposes more general and simple formulation of the phenomenon.	T. Misaiva
Structure-Determined Gain-Band Product of Junction Triode Transistors	Proc. IRE 12/58	Discussion of some fundamental frequency limitations of the junction triode, practical accomplishments with Ge diffused base transistors, and frequency limitations of the junction triode compared with those of the field effect and analog transistors.	J. M. Early

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications Sept. 6, 1955 to Dec. 20, 1955

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Sept. 6, 1955 to Dec. 20, 1955. In subsequent issues, patents issued from Dec. 20, 1955 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear every three months, the treatment given to each item being more detailed.

September 6, 1955

2,717,342 Semiconductor Translating Devices—W. G. Pfann. Assignee: Bell Telephone Laboratories. A device consisting of a semiconductive filament, two low-resistance contacts to said filament, two emitter contacts between said low-resistance contacts, and a *p-n* junction between said emitter contacts.

2,717,343 P-N Junction Transistor—R. N. Hall. Assignee: General Electric Company. A power transistor comprising a semiconductor body having opposing major surfaces, and having along a major dimension thereof zones of alternately opposite conductivity type, said zones forming a series of *p-n* Junctions.

2,717,372 Ferro-Electric Storage Device and Circuit—J. R. Anderson. Assignee: Bell Telephone Laboratories. A memory circuit comprising a condenser with a ferroelectric dielectric material and a diode in parallel with said capacitor and poled to present a high impedance to pulses tending to polarize said material to its initial state of polarization.

September 20, 1955

2,718,613 Transistor Circuit for Operating a Relay—J. R. Harris. Assignee: Bell Telephone Laboratories. Apparatus utilizing a transistor trigger circuit having an "OFF" condition and an "ON" condition.

2,718,615 Liquid Cooling of Dry Disk Rectifiers—J. J. Riley. Assignee: The Taylor-Winfield Corporation. A rectifier arrangement containing tubular conduit members for certain rectifier plates, said tubular conduits being made of heat conductive material and having a wave-shaped form.

2,718,616 Semiconductive Device—M. Conrad. Assignee: Stromberg-Carlson Company. A device having a plurality of conductive elements each having an accessible end, means for supporting said elements relative to each other such that said ends project through an insulating surface, semiconductive means extending over a portion of said ends, and means for establishing electrical contact with the exposed portion of said semiconductive means.

September 27, 1955

2,719,190 High Efficiency Translating Circuit—G. Raisbeck. Assignee: Bell Telephone Laboratories. Apparatus comprising a wave source, a load, two energy paths interconnecting said source and said load, an electron tube amplifier, a transistor amplifier, means for supplying the amplifier outputs to the load in additive relation without impedance inversion, and means for biasing one amplifier for class B operation, and the other for class C operation.

2,719,253 Non Linear Conduction Elements —R. K. Willardson, A. C. Beer, A. E. Middleton. Assignee: Bradley Mining Company. A rectifier comprising a semiconductor and an electrode making contact with the surface thereof, said semiconductor consisting of at least 50% of an element of group III, also including at least 40% aluminum and 50% of an element from group *V* with at least 40% antimony.

2,719,257 Rectified Current Supply System —W. E. Sargeant, W. S. Erwin. Assignee: General Motors Corporation. In combination, an *a-c* voltage source, a saturable reactor having an *a-c* winding in series with the input circuit of a rectifying system, a *d-c* control winding, a reference circuit path, a control circuit path, and an output circuit connected to the *a-c* control winding of the saturable reactor.

October 4, 1955

2,719,799 Zone Melting Furnace and Method of Zone Melting—S. M. Christian. Assignee: Radio Corporation of America. A method which involves forming an elongated charge, establishing a plurality of overlapping heating zones along said charge, successively melting and freezing the respective portions of said charge in successive zones while maintaining said charge stationary in said furnace.

October 11, 1955

2,720,616 Rectifier Assembly—A. S. Vanderhoof. Assignee: None. A rectifier stack assembly comprising spaced parallel upright insulating posts, plates having cut out portions embracing said posts, and metallic spring spacer elements between adjacent plates of the stack.

2,720,617 Transistor Packages—J. J. Sardella. Assignee: Raytheon Manufacturing Company. A transistor package comprising an envelope, a set of insulated leads, a transistor connected to said leads, an interior closed chamber wherein the transistor is separated from said envelope, and a polymeric fluorocarbon casting resin filling said chamber and surrounding said transistor.

October 18, 1955

2,721,269 Error Rate Damping Circuit—L. Wolman. Assignee: Librascope Incorporated. An error rate damping circuit designed to render alternating current servo loop resonant damping means independent of frequency and voltage fluctuations in the current supply over a substantial range.

October 25, 1955

2,721,965 Power Transistor—R. N. Hall. Assignee: General Electric Company. A power transistor comprising a flat slab of semiconductor material of one conductivity type, and a plurality of closely spaced activator large-area-contact members for providing conduction carriers of the opposite conductivity type to those of said slab.

November 1, 1955

2,722,638 Crystal Diode and Method of Making Same—C. E. Atkins. Assignee: Tung-Sol Electric Inc. A crystal diode comprising a vitreous bead, a pair of lead wires and fused thereto, a crystal mounted on the flattened end of one lead wire, a whisker mounted on the other lead and contacting the crystal, and a thermosetting resin embedding said whisker and crystal.

2,722,649 Arcless Switching Device—R. B. Immel, W. B. Guggi. Assignee: Westinghouse Electric Corporation. An *a-c* motor having power leads connected to the phase windings thereof, and power control means for each phase comprising a transistor and means coupled thereto for selectively cutting off the current flow and permitting current flow through the transistor.

2,722,652 Excitation System for Electrical Machines—M. W. Brainard. Assignee: O'Keefe and Merritt Company. (One-Half Interest) The system provides a dry plate selenium rectifier with an electric machine, said rectifier being able to perform the functions of a commutator of slip rings or other mechanical feature of this type.

November 8, 1955

2,723,355 Diode Gate Circuit—R. E. Graham. Assignee: Bell Telephone Laboratories. An electronic gating network having a pair of input and output terminals, an L-network of asymmetrically conducting devices, means for connecting one arm of said network in a series path between an input and an output terminal, a shunt path in the other arm of the

* Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

network, a *a-c* source in parallel with said shunt path, and means for controlling the impedance of said network devices.

2,723,370 Electrically Semiconductive Crystalline Body—S. E. Bradshaw, R. W. Douglas, Assignee: Hazeltine Research Incorporated. A method of production comprising the fusing of a quantity of germanium not greater than 45 mg., cooling said globule-shaped quantity so as to form a spike thereon with said spike having a high concentration of impurities, cutting a slab including said spike from the body and preparing a contact surface on the body.

November 15, 1955

2,724,061 Single Transistor Binary Trigger —R. W. Emery. Assignee: International Business Machines Corporation. An objective of this invention is to provide a simplified binary trigger circuit that requires no adjustment when any circuit component including the transistor is replaced by a component that is within standard manufacturing tolerances.

2,724,077 Asymmetrically Conductive Device—W. C. Dunlap Jr. Assignee: General Electric Company. A current control device comprising a wedge of germanium, a pointed exciter electrode and a pointed collector electrode.

2,724,078 Selenium Rectifiers—R. F. Durst, G. C. Florio, D. W. Black. Assignee: International Telephone and Telegraph Company. In a rectifier: a base plate, a selenium layer thereon, a counter electrode on the selenium layer, and an intermediate layer between the selenium and the counter electrode, said layer consisting of a high molecular weight linear polymeric carbonamide soluble in the lower aliphatic alcohols, together with nitroparafin which contains ¼% to 1% selenium dioxide.

2,724,079 Artificial Barrier Layer Selenium Rectifier—D. W. Black. Assignee: International Telephone & Telegraph Company. A device having between its selenium layer and its counter-electrode a film deposited from a solution of a linear polymeric carbonamide of the type soluble in the lower aliphatic alcohols, and including the addition of magnesium nitrate.

November 22, 1955

2,724,780 Inhibited Trigger Circuits—J. R. Harris. Assignee: Bell Telephone Laboratories. A plurality of trigger circuits, means to apply their outputs to the input of a common load circuit and means to apply a portion of the input of each trigger circuit to the input of each other trigger circuit with the proper polarity to inhibit each of said other trigger circuits.

November 29, 1955

2,725,315 Method of Fabricating Semiconductive Bodies—C. S. Fuller. Assignee: Bell Telephone Laboratories. The method involves heating a body of *p*-type germanium or silicon in the presence of lithium between a temperature of 500 degrees C and the melting point of the semiconductive material.

2,725,316 Method of preparing *P-N* Junctions in Semiconductors—C. S. Fuller. Assignee: Bell Telephone Laboratories. The method involves immersing a body of *p*-type germanium or silicon in a molten solution of lithium in a low melting point metal and removing said body from said solution.

2,725,317 Method of Fabricating and Heat Treating Semiconductors—J. J. Kleimack. Assignee: Bell Telephone Laboratories. The method of fabricating a transistor having a reduced minority carrier storage which comprises electroforming the collector and subjecting the assembled unit to a plurality of temperature cycles from ambient temperature to about 75 degrees C, each cycle lasting one-half hour.

2,725,318 Method of Plastic Working of Semiconductors—C. J. Gallagher. Assignee: General Electric Company. A method of plastically working crystalline germanium which comprises heating said material to a temperature between 500 degrees C and 760 degrees C, applying a deforming force, and annealing the deformed germanium at 500 degrees C for an extended period of time.

2,725,503 Selenium Rectifier Stacks—I. Wilf, M. A. Szalkowski. Assignee: Electronic Devices Inc. A rectifier stack having a parallel spaced array and spacers interposed therebetween, and consisting of thin-walled sleeves having outwardly extending flanges in direct contact with the adjacent plate surfaces.

2,725,504 Hall Effect Device—W. C. Dunlap Jr. Assignee: General Electric Company. A device comprising a single Hall plate having flat opposed major faces and a thickness less than 0.010 inch, two layers of insulation covering said faces, and two ferromagnetic plates covering the insulated layer.

2,725,505 Semiconductor Power Devices—W. M. Webster Jr., J. R. Woolston. Assignee: Radio Corporation of America. A device having therein zones of different conductivity types separated by a rectifying barrier, a quantity of metal integral with at least one of said zones, and a heat dissipating member penetrating into said metal and in close proximity to said barrier.

2,725,506 Point Contact Semiconductor Unit—R. A. Langevin, E. A. Gschwind. Assignee: Clevite Corporation. A point-contact device comprising: a semiconductor; a pair of flexible, resilient, electrode wires; and a housing defining a chamber receiving the semiconductor and formed with spaced passages receiving said electrode wires.

December 6, 1955

2,726,357 Semiconductor Device—R. Sachs. Assignee: Columbia Broadcasting System Inc. The invention provides a device wherein the electrodes are highly resistant to applied torque. The device consists of a cartridge having a central axial opening with at least one electrode inserted therein, said axial opening having longitudinal grooves in the wall thereof, and a semiconducting wafer with a point-contact electrode.

2,726,370 Negative Impedance Converters Employing Transistors—J. G. Linvill, R. L. Wallace Jr. Assignee: Bell Telephone Laboratories. A device comprising a transistor, means for deriving a signal proportional to the voltage appearing across two terminals one of which is connected to the collector and the other to a common point, and means for inverting the phase of this signal and applying it to an impedance element connected between the base and the common point.

December 13, 1955

2,727,146 Sinusoidal Oscillators—K. N. Fromm. Assigne: Westinghouse Electric Corporation. An oscillator having a semiconductive device, a tunable network, means for supplying positive bias between the emitter and a common point, means for supplying negative bias, and a direct connection from the base to said common point.

December 20, 1955

2,727,839 Method of Producing Semiconductive Bodies—M. Sparks. Assignee: Bell Telephone Laboratories. A method which comprises introducing a seed into a molten mass of semiconductive material of one conductivity type of silicon or germanium, said seed being of like material to that of said molten mass, causing the material to flow laterally past said seed, and withdrawing said seed from said mass at a rate equal to the rate of crystallization.

2,727,840 Methods of Producing Semiconductive Bodies—G. K. Teal. Assignee: Bell Telephone Laboratories. A method which comprises melting a mass of a conductivity type determining impurity and germanium or silicon, introducing a seed of the same material into the mass, withdrawing the seed and some of said molten mass, adding a conductivity type determining impurity, withdrawing an additional portion of the molten mass, and allowing the material to crystallize.

2,727,999 Phase Sensitive Demodulators—G. W. Rusler. Assignee: Minneapolis-Honeywell Regulator Company. A circuit having as one objective the realization of a full wave demodulator constructed so as to impress two alternating signals on the primary windings of transformers, thus mixing the two signals in a phase relationship such that a unidirectional output is achieved; said output being a function of the algebraic sum of the input voltages.

2,728,034 Semiconductor Devices With Opposite Conductivity Zones—J. Kurshan. Assignee: Radio Corporation of America. A device comprising a body of semiconducting material having two zones of the same conductivity type separated by a zone of the opposite conductivity type, two low resistance contacts, one to each of said two zones, and a further electrode positioned near the intermediate zone.

2,728,049 Reaction Modulation Circuit—F. M. Riddle. Assignee: California Institute Research Foundation. A modulator oscillator circuit comprising a pair of input terminals, means to apply direct current to said terminals, a diode connected thereacross, a transistor and an oscillator circuit with a tuned circuit.

2,728,053 Transmission Network Using Transistors—J. T. Bangert. Assignee: Bell Telephone Laboratories. A negative-resistance network comprising two transistors, said network having a design objective which consists of improving the transmission characteristics of wave transmission networks by compensating the dissipation associated with the network branches.

[To Be Continued]

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN FEB. 1, 1959 and MAR. 31, 1959 ONLY
Charts of Silicon Zener of Avalanche Diodes, Switching Diodes. Voltage Variable Capacitor Diodes, and other types of diodes will be published in the July issue of SCP.

MANUFACTURERS

AMP—	Amperex Electronic Corp.
AUD—	Audio Devices, Inc.
BEN—	Bendix Aviation Corp.
BER—	Berkshire Labs
BOG—	Bogue Electric Mfg. Co.
BOM—	Bomac Labs
BRA—	Bradley Labs
BTHB—	British Thomson-Houston Export Co., Ltd.
CBS—	CBS-Hytron
CDC—	Continental Device Corp.
COL—	Columbus Electronics Corp.
CTP—	Clevite Transistor Products, Inc.
CSF—	Compagnie Generale de T.S.F.
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GIC—	General Instrument Corp.
GTC—	General Transistor Corp.
HSD—	Hoffman Semiconductor Division
HUG—	Hughes Products Division
IFHS—	Institutet for Halvedarforskning
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
LCTF—	Laboratoire Central de Telecommunications
MAL—	P. R. Mallory & Co., Inc.
MIC—	Microwave Associates, Inc.
MOT—	Motorola, Inc.
MUL—	Mullard, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHM—	Ohmite Manufacturing Co.
PHI—	Philco Corp. Lansdale Tube Company
PSI—	Pacific Semiconductors, Inc.
QSC—	Qutronic Semiconductor Corp.
RAY—	Raytheon Manufacturing Company
RCA—	Radio Corporation of America, Semiconductor Div.
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
THE—	Thermosen, Inc.
TI—	Texas Instruments, Inc.
TKD—	Tekade, Nurnberg, Germany
TOK—	Tokyo Tsushin Kogyo, Ltd.
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
USD—	United States Dynamics Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered diodes and rectifiers.

Continental Device: 1N456, 1N456A, 1N457, 1N457A, 1N458, 1N458A, 1N459, 1N459A, 1N461, 1N461A, 1N462, 1N462A, 1N463, 1N463A, 1N464, 1N464A, 1N482, 1N482A, 1N482B, 1N483, 1N483A, 1N483B, 1N484, 1N484A, 1N484B, 1N485, 1N485A, 1N485B, 1N486, 1N486A, 1N487, 1N487A

Institutet for Halvledarforskning: 1N34, 1N38, 1N54, 1N58

Kemtron: 1N36, 1N39A, 1N39B, 1N40, 1N41, 1N42, 1N44, 1N45, 1N46, 1N47, 1N48, 1N51, 1N60A, 1N63, 1N64, 1N64A, 1N65, 1N66, 1N67, 1N67A, 1N68, 1N68A, 1N69A, 1N70, 1N70A, 1N71, 1N72 1N73, 1N74, 1N75, 1N81, 1N81A, 1N86, 1N87, 1N87A, 1N88, 1N89, 1N90, 1N95, 1N96, 1N97, 1N97A, 1N98, 1N98A, 1N99, 1N99A, 1N100, 1N100A, 1N105, 1N107, 1N108, 1N109, 1N111, 1N112, 1N113, N114, 1N115, 1N116, 1N116A, 1N117, 1N117A, 1N118, 1N118A, 1N126, 1N126A, 1N127, 1N127A, 1N128, 1N128A, 1N132, 1N133, 1N134, 1N198, 1N265, 1N266, 1N267, 1N268, 1N294, 1N295, 1N297, 1N298, 1N299, 1N367, 1N368, 1N530, 1N531, 1N532, 1N533, 1N534, 1N535, 1N536, 1N537, 1N538, 1N539, 1N540, 1N600, 1N1095, 1N1096

Semicon, Inc.: 1N440B, 1N441B, 1N442B, 1N443B, 1N444B, 1N530, 1N531, 1N532, 1N533, 1N534, 1N535, 1N536, 1N537, 1N538, 1N539, 1N540, 1N547, 1N560, 1N561, 1N562, 1N563, 1N599, 1N599A, 1N600, 1N600A, 1N601, 1N601A, 1N602, 1N602A, 1N603, 1N603A, 1N604, 1N604A, 1N605, 1N605A, 1N606, 1N606A, 1N1095, 1N1096, 1N1100, 1N1101, 1N1102, 1N1103, 1N1104, 1N1105, 1N1763, 1N1764.

Silicon Transistor: 1N456, 1N457, 1N458, 1N459, 1N461, 1N462, 1N463, 1N464, 1N482, 1N482A, 1N482B, 1N483, 1N483A, 1N483B, 1N484, 1N484A, 1N484B, 1N486, 1N486A, 1N487, 1N487A, 1N625, 1N626, 1N627, 1N628, 1N629, 1N658

Texas Instruments: 1N457, 1N458, 1N459, 1N461, 1N462, 1N463, 1N464, 1N482B, 1N483B, 1N484B, 1N485B, 1N486B, 1N487B, 1N488B.

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA)	(volts)	(°C)	MFR. (See code at start of charts)
1N1130	1	Si	1500	1500	300	4.5	.150	150A	4.0	100	1500	75A	INRC
1N1131	1	Si	1500	1500	300	4.5	.150	150A	4.0	100	1500	75A	INRC
1N2329	1	Si	200	200	1.5	1.1	1.5	50A		10	200	25A	TI
1N2330	1	Si	300	300	1.5	1.1	1.5	50A		10	300	25A	TI
1N2331	1	Si	400	400	1.5	1.1	1.5	50A		10	400	25A	TI
1N2332	1	Si	500	500	1.5	1.1	1.5	50A		10	500	25A	TI
1N2333	1	Si	600	600	1.5	1.1	1.5	50A		10	600	25A	TI
1N2334	2	Si	50	50	50	1.0	50	150C		10ma	50	200J	TI
1N2335	2	Si	100	100	50	1.0	50	150C		10ma	100	200J	TI
1N2336	2	Si	200	200	50	1.0	50	150C		10ma	200	200J	TI
1N2337	2	Si	300	300	50	1.0	50	150C		10ma	300	200J	TI
1N2338	2	Si	400	400	50	1.0	50	150C		5.0ma	400	200J	TI
1N2339	2	Si	500	500	50	1.0	50	150C		5.0ma	500	200J	TI
1N2340	2	Si	600	600	50	1.0	50	150C		5.0ma	600	200J	TI
1N2341	2	Si	50	50	30	1.0	30	150C		10ma	50	200J	TI
1N2342	2	Si	100	100	30	1.0	30	150C		10ma	100	200J	TI
1N2343	2	Si	200	200	30	1.0	30	150C		10ma	200	200J	TI
1N2344	2	Si	300	300	30	1.0	30	150C		10ma	300	200J	TI
1N2345	2	Si	400	400	30	1.0	30	150C		5.0ma	400	200J	TI
1N2346	2	Si	500	500	30	1.0	30	150C		5.0ma	500	200J	TI
1N2347	2	Si	600	600	30	1.0	30	150C		5.0ma	600	200J	TI
1N2373	1	Si	600	600	250	3.0	.100	100A		100	600	100A	INRC
1N2374	1	Si	1000	1000	250	3.0	.100	100A		100	1000	100A	INRC
1N2375	1	Si	1500	1500	200	4.5	.100	100A		100	1500	100A	INRC
1N2376	1	Si	2000	2000	200	7.5	.100	100A		100	2000	100A	INRC

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier
Ø Insulated Base
5. Controlled Rectifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

☒ Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ — Inlet Temperature of Coolant

Type No.

† — Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

Under E_f

☒ - at 125°C

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)		MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_o @ T (uA)	(volts)	(°C)	MFR. (See code at start of charts)
1N2377	1	Si	2400	2400	150	9.0	.075	100A		100	2400	100A	INRC
1N2378	1	Si	3000	3000	150	9.0	.075	100A		100	3000	100A	INRC
1N2379	1	Si	4000	4000	100	15	.050	100A		100	4000	100A	INRC
1N2380	1	Si	6000	6000	100	22.5	.050	100A		100	6000	100A	INRC
1N2381	1	Si	10K	10K	75	37.5	.025	100A		100	10K	100A	INRC
3A305	5	Si	30	30			.75	100C		10	30	25	SSP
3A605	5	Si	60	60			.75	100C		10	60	25	SSP
3A1005	5	Si	100	100			.75	100C		10	150	25	SSP
3A1505	5	Si	150	150			.75	100C		10	200	25	SSP
3A2005	5	Si	200	200			.75	100C		10	200	25	SSP
4A11N1	1	Si	50	35	35A	1.1	35	135C		20	50	165A	FAN
4A12N1	1	Si	100	70	35A	1.1	35	135C		20	100	165A	FAN
4A13N1	1	Si	150	105	35A	1.1	35	135C		20	150	165A	FAN
4A14N1	1	Si	200	140	35A	1.1	35	135C		20	200	165A	FAN
4A15N1	1	Si	250	175	35A	1.1	35	135C		20	250	165A	FAN
4A16N1	1	Si	300	210	35A	1.1	35	135C		20	300	165A	FAN
4A17N1	1	Si	350	245	35A	1.1	35	135C		20	350	165A	FAN
4A18N1	1	Si	400	280	35A	1.1	35	135C		20	400	165A	FAN
4A11N2	1	Si	50	35	35A	1.1	35	135C		20	50	165A	FAN
4A12N2	1	Si	100	70	35A	1.1	35	135C		20	100	165A	FAN
4A13N2	1	Si	150	105	35A	1.1	35	135C		20	150	165A	FAN
4A14N2	1	Si	200	140	35A	1.1	35	135C		20	200	165A	FAN
4A15N2	1	Si	250	175	35A	1.1	35	135C		20	300	165A	FAN
4A16N2	1	Si	300	210	35A	1.1	35	135C		20	300	165A	FAN
4A17N2	1	Si	350	245	35A	1.1	35	135C		20	350	165A	FAN
4A18N2	1	Si	400	280	35A	1.1	35	135C		20	400	165A	FAN
4A11P1	1	Si	50	50	35A	1.1	35	135C		20	50	165A	FAN
4A12P1	1	Si	100	70	35A	1.1	35	135C		20	100	165A	FAN
4A13P1	1	Si	150	105	35A	1.1	35	135C		20	150	165A	FAN
4A14P1	1	Si	200	140	35A	1.1	35	135C		20	200	165A	FAN
4A15P1	1	Si	250	175	35A	1.1	35	135C		20	250	165A	FAN
4A16P1	1	Si	300	210	35A	1.1	35	135C		20	300	165A	FAN
4A17P1	1	Si	350	245	35A	1.1	35	135C		20	350	165A	FAN
4A18P1	1	Si	400	280	35A	1.1	35	135C		20	400	165A	FAN
4A11P2	1	Si	50	35	35A	1.1	35	135C		20	50	165A	FAN
4A12P2	1	Si	100	70	35A	1.1	35	135C		20	100	165A	FAN
4A13P2	1	Si	150	105	35A	1.1	35	135C		20	150	165A	FAN
4A14P2	1	Si	200	140	35A	1.1	35	135C		20	200	165A	FAN
4A15P2	1	Si	250	175	35A	1.1	35	135C		20	250	165A	FAN
4A16P2	1	Si	300	210	35A	1.1	35	135C		20	300	165A	FAN
4A17P2	1	Si	350	245	35A	1.1	35	135C		20	350	165A	FAN
4A18P2	1	Si	400	280	35A	1.1	35	135C		20	400	165A	FAN
6A11N1	1	Si	50	35	22A	1.1	22	135C		10	50	165A	FAN
6A12N1	1	Si	100	70	22A	1.1	22	135C		10	100	165A	FAN
6A13N1	1	Si	150	105	22A	1.1	22	135C		10	150	165A	FAN
6A14N1	1	Si	200	140	22A	1.1	22	135C		10	200	165A	FAN
6A15N1	1	Si	250	175	22A	1.1	22	135C		10	300	165A	FAN
6A16N1	1	Si	300	210	22A	1.1	22	135C		10	300	165A	FAN
6A17N1	1	Si	350	245	22A	1.1	22	135C		10	350	165A	FAN
6A18N1	1	Si	400	280	22A	1.1	22	135C		10	400	165A	FAN
6A11N2	1	Si	50	35	22A	1.1	22	135C		10	50	165A	FAN
6A12N2	1	Si	100	70	22A	1.1	22	135C		10	100	165A	FAN
6A13N2	1	Si	150	105	22A	1.1	22	135C		10	150	165A	FAN
6A14N2	1	Si	200	140	22A	1.1	22	135C		10	200	165A	FAN
6A15N2	1	Si	250	175	22A	1.1	22	135C		10	250	165A	FAN
6A16N2	1	Si	300	210	22A	1.1	22	135C		10	300	165A	FAN
6A17N2	1	Si	350	245	22A	1.1	22	135C		10	350	165A	FAN
6A18N2	1	Si	400	280	22A	1.1	22	135C		10	400	165A	FAN
6A11P1	1	Si	50	35	22A	1.1	20	135C		10	50	165A	FAN
6A12P1	1	Si	100	70	22A	1.1	20	135C		10	100	165A	FAN
6A13P1	1	Si	150	105	22A	1.1	20	135C		10	150	165A	FAN
6A14P1	1	Si	200	140	22A	1.1	20	135C		10	200	165A	FAN
6A15P1	1	Si	250	175	22A	1.1	20	135C		10	250	165A	FAN
6A16P1	1	Si	300	210	22A	1.1	20	135C		10	300	165A	FAN
6A17P1	1	Si	350	245	22A	1.1	20	135C		10	350	165A	FAN
6A18P1	1	Si	400	280	22A	1.1	20	135C		10	400	165A	FAN
6A11P2	1	Si	50	35	22A	1.1	20	135C		10	50	165A	FAN
6A12P2	1	Si	100	70	22A	1.1	20	135C		10	100	165A	FAN
6A13P2	1	Si	150	105	22A	1.1	20	135C		10	150	165A	FAN
6A14P2	1	Si	200	140	22A	1.1	20	135C		10	200	165A	FAN
6A15P2	1	Si	250	175	22A	1.1	20	135C		10	250	165A	FAN
6A16P2	1	Si	300	210	22A	1.1	20	135C		10	300	165A	FAN
6A17P2	1	Si	350	245	22A	1.1	20	135C		10	350	165A	FAN
6A18P2	1	Si	400	280	22A	1.1	20	135C		10	400	165A	FAN

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(E_f volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	(°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (I_b uA)	(E_b volts)	(T °C)	MFR. (See code at start of charts)
300A	2	Si	50	50			70	190J	1.2	30ma	50	190J	WEST
300B	2	Si	100	100			70	190J	1.2	30ma	100	190J	WEST
300C	2	Si	150	150			70	190J	1.2	30ma	150	190J	WEST
300D	2	Si	200	200			70	190J	1.2	30ma	200	190J	WEST
300E	2	Si	250	250			70	190J	1.2	30ma	250	190J	WEST
300F	2	Si	300	300			70	190J	1.2	30ma	300	190J	WEST
300G	2	Si	350	350			70	190J	1.2	30ma	350	190J	WEST
300H	2	Si	400	400			70	190J	1.2	30ma	400	190J	WEST
300K	2	Si	500	500			70	190J	1.2	30ma	500	190J	WEST
3005	1	Si	50	35	1200	1.2	20	150C	1.0	10ma	50	150C	SYN
3010	1	Si	100	70	1200	1.2	20	150C	1.0	10ma	100	150C	SYN
3015	1	Si	150	105	1200	1.2	20	150C	1.0	10ma	150	150C	SYN
3020	1	Si	200	140	1200	1.2	20	150C	1.0	10ma	200	150C	SYN
3025	1	Si	250	175	1200	1.2	20	150C	1.0	10ma	250	150C	SYN
3030	1	Si	300	210	1200	1.2	20	150C	1.0	10ma	300	150C	SYN
3035	1	Si	350	245	1200	1.2	20	150C	1.0	10ma	350	150C	SYN
3040	1	Si	400	280	1200	1.2	20	150C	1.0	10ma	400	150C	SYN
AA10	2	Si	100	100	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA20	2	Si	200	200	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA30	2	Si	300	300	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA40	2	Si	400	400	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA50	2	Si	500	500	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA60	2	Si	600	600	2A	1.0	2.0	135C	.50	10	100	25	VIC
BA10	2	Si	100	100	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA20	2	Si	200	200	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA30	2	Si	300	300	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA40	2	Si	400	400	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA50	2	Si	500	500	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA60	2	Si	600	600	8A	1.0	8.0	135C	.50	10	100	25	VIC
CA10	2	Si	100	100	12A	1.0	12	135C	.50	10	100	25	VIC
CA20	2	Si	200	200	12A	1.0	12	135C	.50	10	100	25	VIC
CA30	2	Si	300	300	12A	1.0	12	135C	.50	10	100	25	VIC
CA40	2	Si	400	400	12A	1.0	12	135C	.50	10	100	25	VIC
CA50	2	Si	500	500	12A	1.0	12	135C	.50	10	100	25	VIC
CA60	2	Si	600	600	12A	1.0	12	135C	.50	10	100	25	VIC
CD1111	1	Si		35	250	1.0				5.0	35	150	CDC
CD1112	1	Si		70	250	1.0				5.0	70	150	CDC
CD1113	1	Si		130	250	1.0				5.0	130	150	CDC
CD1114	1	Si		180	250	1.0				5.0	225	150	CDC
CD1115	1	Si		225	250	1.0				5.0	300	150	CDC
CD1116	1	Si		300	250	1.0				5.0	300	150	CDC
HPR50	2	Si	50	35	20	1.0	35	25A	1.0	1000	50	25A	USS
HPR100	2	Si	100	70	20	1.0	35	25A	1.0	1000	100	25A	USS
HPR200	2	Si	200	140	20	1.0	35	25A	1.0	1000	200	25A	USS
HPR300	2	Si	300	210	20	1.0	35	25A	1.0	1000	300	25A	USS
HPR400	2	Si	400	280	20	1.0	35	25A	1.0	1000	400	25A	USS
HPR500	2	Si	500	350	20	1.0	35	25A	1.0	1000	500	25A	USS
HPR600	2	Si	600	420	20	1.0	35	25A	1.0	1000	600	25A	USS
MR5	1,2,3	Si	50	50	3.0A	1.0	3.0A	150		20	50	25	TSC-6
MR10	1,2,3	Si	100	100	3.0A	1.0	3.0A	150		20	100	25	TSC-6
MR15	1,2,3	Si	150	150	3.0A	1.0	3.0A	150		20	150	25	TSC-6
MR20	1,2,3	Si	200	200	3.0A	1.0	3.0A	150		20	200	25	TSC-6
MR25	1,2,3	Si	250	250	3.0A	1.0	3.0A	150		20	250	25	TSC-6
MR30	1,2,3	Si	300	300	3.0A	1.0	3.0A	150		20	300	25	TSC-6
MR40	1,2,3	Si	400	400	3.0A	1.0	3.0A	150		20	400	25	TSC-6
MR50	1,2,3	Si	500	500	3.0A	1.0	3.0A	150		20	500	25	TSC-6
MR60	1,2,3	Si	600	600	3.0A	1.0	3.0A	150		20	600	25	TSC-6
MR70	1,2,3	Si	700	700	3.0A	1.0	3.0A	150		20	700	25	TSC-6
MR80	1,2,3	Si	800	800	3.0A	1.0	3.0A	150		20	800	25	TSC-6
MS5	1,2,3	Si	50	50	6.0A	1.0	3.0A	150		20	50	25	TSC-6

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier
Ø Insulated Base
5. Controlled Rectifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

☒ Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ — Inlet Temperature of Coolant

Type No.

† — Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

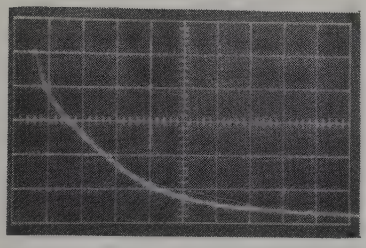
Under E_f

☒ - at 125°C

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(E_f volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	(°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA)	(E_b volts)	(°C)	MFR. (See code at start of charts)
MS10	1,2,3	Si	100	100	6.0A	1.0	3.0A	150		20	100	25	TSC-6
MS15	1,2,3	Si	150	150	6.0A	1.0	3.0A	150		20	150	25	TSC-6
MS20	1,2,3	Si	200	200	6.0A	1.0	3.0A	150		20	200	25	TSC-6
MS25	1,2,3	Si	250	250	6.0A	1.0	3.0A	150		20	250	25	TSC-6
MS30	1,2,3	Si	300	300	6.0A	1.0	3.0A	150		20	300	25	TSC-6
MS40	1,2,3	Si	400	400	6.0A	1.0	3.0A	150		20	400	25	TSC-6
MS50	1,2,3	Si	500	500	6.0A	1.0	3.0A	150		20	500	25	TSC-6
MS60	1,2,3	Si	600	600	6.0A	1.0	3.0A	150		20	600	25	TSC-6
MS70	1,2,3	Si	700	700	6.0A	1.0	3.0A	150		20	700	25	TSC-6
MS80	1,2,3	Si	800	800	6.0A	1.0	3.0A	150		20	800	25	TSC-6
MT5	1,2,3	Si	50	50	12A	1.0	3.0A	150		100	50	25	TSC-6
MT10	1,2,3	Si	100	100	12A	1.0	3.0A	150		100	100	25	TSC-6
MT15	1,2,3	Si	150	150	12A	1.0	3.0A	150		100	150	25	TSC-6
MT20	1,2,3	Si	200	200	12A	1.0	3.0A	150		100	200	25	TSC-6
MT25	1,2,3	Si	250	250	12A	1.0	3.0A	150		100	250	25	TSC-6
MT30	1,2,3	Si	300	300	12A	1.0	3.0A	150		100	300	25	TSC-6
MT40	1,2,3	Si	400	400	12A	1.0	3.0A	150		100	400	25	TSC-6
MT50	1,2,3	Si	500	500	12A	1.0	3.0A	150		100	500	25	TSC-6
MT60	1,2,3	Si	600	600	12A	1.0	3.0A	150		100	600	25	TSC-6
MT70	1,2,3	Si	700	700	12A	1.0	3.0A	150		100	700	25	TSC-6
MT80	1,2,3	Si	800	800	12A	1.0	3.0A	150		100	800	25	TSC-6
OA31	2	Ge	85		12A	.70	3.5	45A	.54	4000	85	75A	MUL
OA47	1	Ge	25	15	.10	.17							MUL
OA86	1	Ge	90	60	.10	.25							MUL
OA90	1	Ge	30		.10	.25	.01	75A	1.5	1500	30	60A	MUL
OA200	1	Si	50		.10	.53	.05	125A	.97	5.0	50	100A	MUL
OA202	1	Si	150		.10	.53	.03	125A	.80	5.0	150	100A	MUL
OA210	2	Si	400		10	.64	.50	70A	1.05	45	400	125A	MUL
OA211	2	Si	800		10	.64	.40	60A	1.0	15	700	125A	MUL
OA214	2	Si	700		10	.64	.50	70A	1.05	65	700	125A	MUL
S16	1,2	Si	400	400	500	1.2	.50	80	.90	100	400	25	SCN
S17	1,2	Si	200	200	500	1.2	.50	80	.90	200	200	25	SCN
S19	1,2	Si	400	400	300	1.2	.30	80	1.5	1500	400	25	SCN
S20	1,2,3	Si	800	800	500	1.2	.50	80	.90	10	800	25	SCN
S21	1,2,3	Si	30	30	750	1.2	.75	80	.90	10	30	25	SCN
S22	1,2,3	Si	50	50	500	1.2	.50	80	.90	10	50	25	SCN
S23	1,2	Si	600	600	500	1.2	.50	80	.90	100	600	25	SCN
S24	1,2,3	Si	1000	1000	500	1.2	.50	80	.90	10	1000	25	SCN
S30	1,2,3	Si	600	600	750	1.1	.75	80	.90	1.0	600	25	SCN
S91	1,2	Si	100	30	150	.90	.15	55	.90	2700	100	55	SCN
S92	1,2	Si	200	65	100	.90	.10	55	.90	1900	200	55	SCN
S93	1,2	Si	300	100	75	.90	.075	55	.90	1200	300	55	SCN
TK21	2	Si	200	200	750	1.0	.50	150A		300	200	150A	TRA
TK41	2	Si	400	400	750	1.0	.50	150A		300	400	150A	TRA
TK61	2	Si	600	600	750	1.0	.50	150A		300	600	150A	TRA
TM8	2	Si	50	50	6.0A	1.1	6.0	150C		2.0ma	50	150C	TRA
TM18	2	Si	100	100	6.0A	1.1	6.0	150C		2.0ma	100	150C	TRA
TM28	2	Si	200	200	6.0A	1.1	6.0	150C		2.0ma	200	150C	TRA
TM38	2	Si	300	300	6.0A	1.1	6.0	150C		2.0ma	300	150C	TRA
TM48	2	Si	400	400	6.0A	1.1	6.0	150C		2.0ma	400	150C	TRA
TM58	2	Si	500	500	6.0A	1.1	6.0	150C		2.0ma	500	150C	TRA
TM68	2	Si	600	600	6.0A	1.1	6.0	150C		2.0ma	600	150C	TRA
TR53	2	Si	50	50	100A	1.5	35	150C		5.0ma	50	150C	TRA
TR103	2	Si	100	100	100A	1.5	35	150C		5.0ma	100	150C	TRA
TR153	2	Si	150	150	100A	1.5	35	150C		5.0ma	150	150C	TRA
TR203	2	Si	200	200	100A	1.5	35	150C		5.0ma	200	150C	TRA
TR253	2	Si	250	250	100A	1.5	35	150C		5.0ma	250	150C	TRA
TR303	2	Si	300	300	100A	1.5	35	150C		5.0ma	300	150C	TRA
TR353	2	Si	350	350	100A	1.5	35	150C		5.0ma	350	150C	TRA
TR403	2	Si	400	400	100A	1.5	35	150C		5.0ma	400	150C	TRA
X6F5	2	Si	50	50			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F10	2	Si	100	100			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F15	2	Si	150	150			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F20	2	Si	200	200			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F30	2	Si	300	300			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F40	2	Si	400	400			6.0	50A	.50	2.5ma(4)		100C	INRC
X6F50	2	Si	500	500			6.0	50A	.50	2.5ma(4)		100C	INRC
X12F5	2	Si	50	50			12	30A	.50	2.5ma(4)		100C	INRC
X12F10	2	Si	100	100			12	30A	.50	2.5ma(4)		100C	INRC
X12F15	2	Si	150	150			12	30A	.50	2.5ma(4)		100C	INRC
X12F20	2	Si	200	200			12	30A	.50	2.5ma(4)		100C	INRC
X2F30	2	Si	300	300			12	30A	.50	2.5ma(4)		100C	INRC
X12F40	2	Si	400	400			12	30A	.50	2.5ma(4)		100C	INRC
X12F50	2	Si	500	500			12	30A	.50	2.5ma(4)		100C	INRC

Semiconductor Lifetime Measuring Equipment

MODEL LM-1



Model LM-1 is a reliable instrument for measuring Lifetimes as short as one microsecond. It is so designed as to accommodate large or small samples including cylindrical ingots.

Semiconductor Lifetime Measuring Equipment consists of a spark gap type light source of 1 microsecond total duration and adequate intensity to inject the order of ten to the thirteenth power carriers per cubic centimeter. It is exceptionally useful in measuring minority carrier lifetime, drift mobility and photo-effects in semiconductors. The flash has a rise time of 0.3 microseconds and decays exponentially with a time constant of less than 0.5 microseconds. It flashes at a rate of 1 or 2 times per second when free running. Power requirements are 50 watts at 115 volts 60 cps. Has synch. output for triggering scope, battery supply and auxiliary measuring equipment. This permits the measurement of lifetime by observing the decay of the photo conductive current on the oscilloscope (as shown above).

To demonstrate the effectiveness of the LM-1 Lifetime Tester, send us a sample of your semi-conductor material. Within 48 hours of receipt we will return sample and photograph similar to above of its photo conductive current decay.

OPERATING DATA

Width of light pulse	1 microsecond
Ringing Frequency	6 megacycles
Firing Voltage, Max.	10 KV
Discharge Capacitor	.02 Mfd.
Lifetime Measurement Range	Down to 1 microsecond
Accuracy	Below 40% between 1 & 2 microseconds, 10% above 2 microseconds
Trigger	Positive
Trigger Amplitude	40 V

SAMPLE SIZE

Accommodates samples between ½ inch and 12 inches in length.

POWER SUPPLY

Rating	105-125 volts, 50-60 cycles
Power Consumption	50 watts
Fuse Protection	1 ampere

BATTERIES

Trap Lite	7.5 VDC
Measuring Circuit	22.5 VDC

ELECTRO IMPULSE Laboratory

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Circle No. 30 on Reader Service Card

Industry News

Chicago Telephone Supply Corporation, Elkhart, Indiana has appointed International Resistance Company, Philadelphia, Penna., its sales agent for the CTS line of distributor military and industrial controls and replacement controls marketed through distributors. In addition, IRC's foreign licensees will be adding the manufacture of CTS variable resistors to their product lines. CTS has purchased and will operate IRC's variable resistor manufacturing plant in Asheville, North Carolina. Service from the Asheville plant to all customers will continue without interruption. All variable resistor products of both companies will continue to be manufactured. The basis for the agreement lay in the fact that the two firms are essentially non-competitive and complement each other in many ways. IRC will utilize CTS's manufacturing skill, techniques, know-how and facilities. CTS will utilize IRC's marketing skill, techniques, know-how and facilities in distributor sales and foreign manufacturing.

Factory sales of Transistors in February increased over January and were considerably over February 1958, according to the latest EIA report released recently. February sales of these semiconductor devices totaled 5,393,377 valued at $14,550,056 compared with 5,195,317 transistors valued at $13,626,886 sold in January and 3,106,708 sold in February 1958 worth $6,806,562. Cumulative transistor sales totaled 10,588,694 valued at $28,176,942 compared with 6,061,955 worth $13,510,945 sold during the like two-months period last year.

Acquisition of a substantial interest in the newly-organized PAM Associates, Inc., Baltimore, formed for development and production of noise control, and shock and vibration test equipment, by Tenney Engineering, Inc., was announced by the two companies recently. PAM Associates, which is headed by former Martin Company engineers, "will provide engineering resources that will supplement those of Tenney, particularly in the fields of shock- and vibration-testing, and noise suppression. The effect will be to further broaden and strengthen the Tenney organization in all important areas of environmental test equipment," according to Saul S. Schiffman, chairman, and Monroe Seligman, president of Tenney. The officers of PAM Associates are: J. William Rice, Jr., president; Edward J. Kirchman, vice president engineering, and Avery L. Oven II, vice president research.

The Third National Convention on Military Electronics, sponsored by the Professional Group on Military Electronics, will be held June 29-July 1, 1959, at the Sheraton-Park Hotel, Washington, D. C. The technical program includes more than 100 papers covering these topics: missile guidance; radar techniques; operations research and tactics; data transmission and processing; space electronics; instrumentation, (two sessions); navigation, surveying and reconnaissance; communications (two sessions); space propulsion; missile electronics; radar systems and equipment; computers; components; space communication; detection and tracking; space guidance and tracking; simulation; navigation and reconnaissance; guidance; reliability. The Air Research and Development Command (ARDC) will sponsor 5 classified sessions during the Convention.

A new group of low-melting glass compositions with far-reaching implications in the manufacture of moisture-sensitive devices has recently been developed by Drs. S. S. Flaschen and A. D. Pearson of Bell Telephone Laboratories. Composed of varying proportions of sulfur or selenium and the heavy metals arsenic and thallium, the glasses become very fluid at temperatures between 125 and 350°C, a temperature range 300 to 400°C lower than any previously known low-melting glass. Coating of semiconducting devices with these low-melting glasses is under study. In experiments with silicon diodes, for example, excellent initial characteristics have been attained. In addition, improvements have been observed when such units were heated or operated.

Westinghouse Electric Corporation has announced that agreements have been completed with the Dow Corning Corporation and Monsanto Chemical Company, licensing them to produce and sell ultrapure silicon. Both companies have been provided with patent rights and technological information on the Siemens-Westinghouse process which makes it possible to manufacture ultrapure silicon. The process originated with inventions and developments by the Siemens & Halske and Siemens-Schuckert Companies in Germany, and from supplemental contributions by scientists and engineers at the Westinghouse Research Laboratories and semiconductor department. Westinghouse is producing pilot quantities of this silicon at the semiconductor department's plant in Youngwood where the company manufactures its own semiconductor devices using this material.

A new solar battery for space vehicles, which uses a high-temperature compound called gallium arsenide to transform light into electricity, and a radio system using a new high-temperature diode of the same material, was demonstrated for the first time by RCA. The solar battery, developed under U. S. Army Signal Corps sponsorship by scientists of RCA Laboratories, was shown powering a miniature ratio transmitter of a model satellite which uses a new gallium arsenide "tunnel" diode. Development of the high-temperature diodes has taken place at RCA Laboratories under the sponsorship of the U. S. Air Force Electronic Components Laboratory, Wright Air Development Center at Dayton, Ohio. The battery and transmitter were exhibited by the RCA Semiconductor and Materials Division at the National Aeronautical Electronics Conference May 4, 5, and 6 in Dayton.

In a move to provide better service for its industrial customers as well as the armed services, Raytheon Company has transferred its Special Microwave Device Group to the company's Industrial Apparatus Division. An integrated business with its own research, development, production, and sales staffs, the group started in the Research Division where it had been assigned while its products and techniques were being developed and were gaining acceptance. Dr. Howard Scharfman heads the group which is expected to number 75 by year's end. Basing projections on continued growth in present product areas without considering possible new additions to the line, Dr. Scharfman expects the group to grow to at least 125 by the end of next year and to double that by the end of 1963.

Palmer Associates Inc., 55 Hall Street, Brockton, Mass., has started in the business of manufacturing glass-to-metal seals. Some of the products they are producing are compression and matched seals, multiple headers, transistor closures, crystal bases, single terminals, miniature seals, etc. The Technical Director is V. Palmeri.

Advanced concepts in solid state physics were featured by the Delco Radio Division in the General Motors exhibit at the first World Congress of Flight April 12-19 at Las Vegas. Delco Radio's theme at the show was "Power through Solid State Physics." Exhibits included a thermoelectric generator, a silicon solar cell array, a model circuit typifying a missile computer, a frequency divider, a static inverter, and power transistors.

CBS-Hytron is changing its name to CBS Electronics, effective July 1, it was announced by Dr. Frank Stanton, president of Columbia Broadcasting System, Inc., at the recent annual meeting of CBS stockholders. Plans to build a $5 million semiconductor plant at Lowell, Massachusetts, to supplement its present one there were announced. Construction of the new 160,000-square foot facility is under way and it will be completed early next year.

Transistor components that meet unusually-stringent specifications and are custom-adapted to unorthodox metallurgical and production requirements are offered by Semi-Alloys, Inc., a newly-formed company at 550 South Fulton Avenue, Mount Vernon, New York. Norman Hascoe is president of the new manufacturing concern, and Gerald Gould is secretary-treasurer. Among its offerings, Semi-Alloys is prepared to supply spheres, pellets, and preforms. The firm will provide personal consultation on the metallurgical and production problems of its customers.

25
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Since 1934 when the Indium Corporation was formed and produced the first commercial amounts of Indium, we have gained in knowledge and in service for all conceivable uses for Indium. Why not write us today . . . our quarter-century of technical knowledge is at your service.
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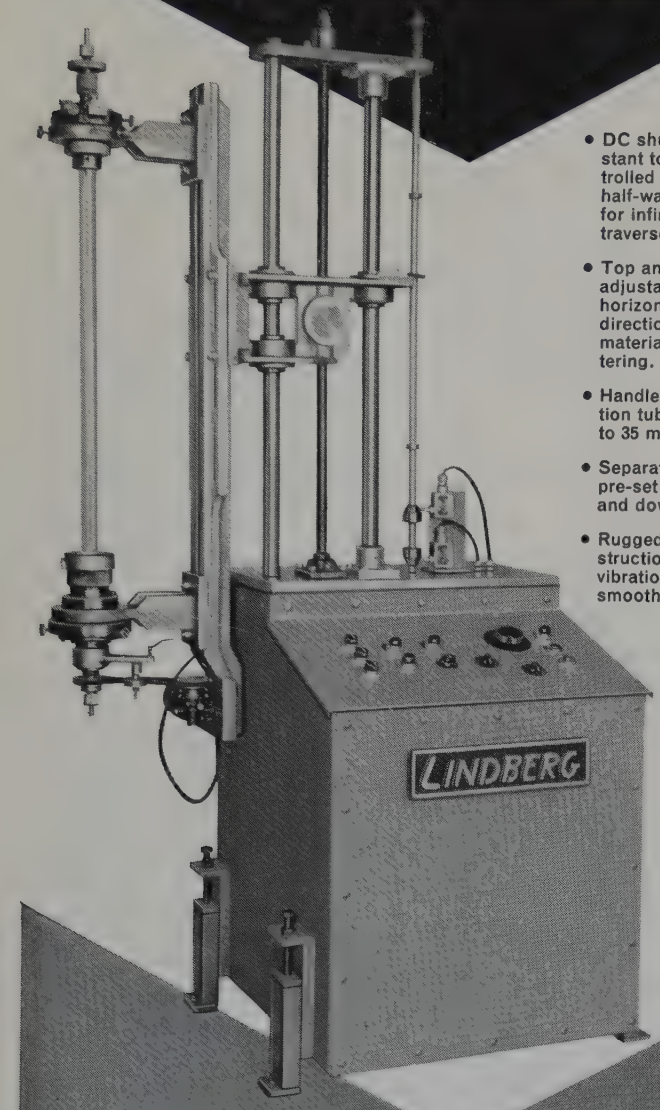

- DC shunt-wound, constant torque motor controlled by thyratron half-wave rectifier for infinitely variable traverse speeds.
- Top and bottom holders adjustable in both horizontal and vertical directions for easy material and seed centering.
- Handles quartz protection tubes up to 35 mm diameter
- Separate controls can be pre-set for up travel and down travel speeds.
- Rugged, accurate construction eliminates vibration and provides smooth traversing.

This new Lindberg vertical floating zone scanner has been expertly designed to provide more accurate and precise production of high purity semi-conductors and metals. Write for Bulletin 1600.

LINDBERG HIGH FREQUENCY DIVISION

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IRE Review

(*from page 23*)

New Coating Process

Partial coating of base metals used as tabs in the manufacture of transistors has been achieved through a new process developed by Alpha Metals, Inc., producers of materials for semiconductors. Through this process the coating can be applied to one side of the base metal only. If desired, an overlay of a full coating, an edge coating, or a center coating can be applied. Another major advantage of this development is that a larger variety of alloys can be used. Typical of the metals and their alloys used for coating through this process are tin, tin-antimony, tin-gallium, lead, lead-antimony, tin-lead-gold, tin-lead-silver, indium, indium-gallium. These solder alloys can be placed on such materials as copper, nickel, kovar and rodar.

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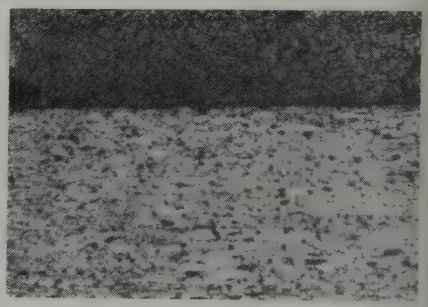

Measuring Equipment

Electro Impulse Laboratory Semiconductor Lifetime Measuring Equipment consists of a spark gap type light source of 1 microsecond total duration and adequate intensity to inject the order often to the thirteenth power carriers per cubic centimeter. It is exceptionally useful in measuring minority carrier lifetime, drift mobility and photo-effects in semiconductors. The flash has a rise time of 0.3 microseconds and decays exponentially with a time constant of less than 0.5 microseconds. It flashes at a rate of 1 to 2 times per second when free running. Power requirements are 65 watts at 115 volts 60 cps. Has synch. output for triggering scope, battery supply and auxiliary measuring equipment. This permits the measurement of lifetime by observing the decay of the photo conductive current on the oscilloscope. Has DC light supply for radiating sample to fill traps.

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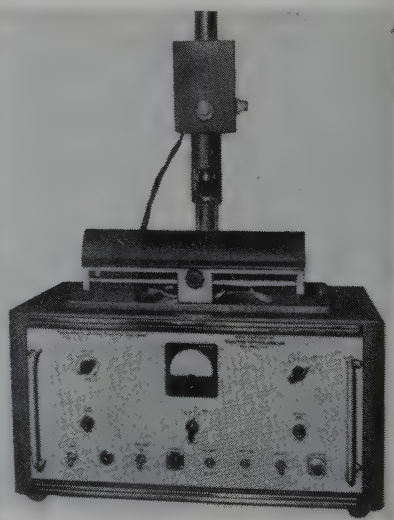

High-Frequency Transistor

Amperex OC 170 alloy-diffused high-frequency germanium transistor. For application as oscillator-mixer in short-wave receivers and as I.F. amplifier in F.M. receivers. Cut-off frequency is 70 Mc/s. Collector current, I_{CBO} = 2 uA, collector breakdown voltage $-V_{CB}$ = min. 20 volts, emitter breakdown voltage $-V_{EB}$ = min. 5 volts.

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Circuit Packages

Raytheon Circuit Packages are being used by many electronic equipment manufacturers to simplify equipment assembly, reduce production errors, and increase reliability. These compact assemblies contain semiconductor devices and other components connected to provide the desired circuit. Many different types of Circuit Packages are available including Bridge Rectifiers, Phase comparators, Diode Switches, Amplifiers, and Flip-Flops. In addition, others can be designed to meet specific requirements.

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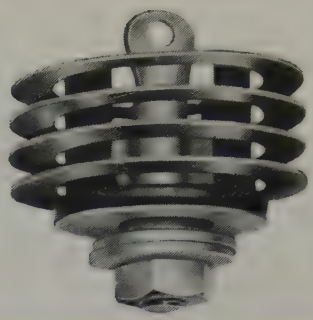

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Miniature Capacitors

Sprague Electric Type 40D tubular aluminum electrolytic capacitors. Operating temperature range: —40 C to +85 C. Designed for more than 10 years service life under typical operating conditions in actual circuit applications. Mechanical construction assures freedom from open circuits. Withstands exposure to high ambient temperatures without leaking. Ultra-low leakage currents are accomplished through special design and processing techniques. For applications requiring an insulated case, Sprague furnishes both an outer insulation of flexible plastic for hand equipment assembly methods and a phenolic outer tube for machine insertion on printed wiring boards.

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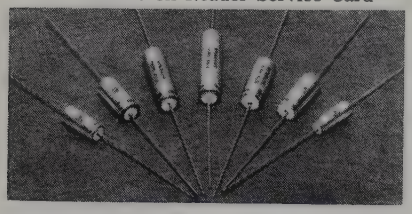

Multi-Unit Transistor

A multi-unit transistor which makes possible battery-operated radio receivers having increased sensitivity and fewer component parts was exhibited by the RCA Semiconductor and Materials Division. Called a diode-triode transistor, the development type is a semiconductor device combining two different units in one metal case. It consists of an alloyed p-n junction (diode unit) for use as an audio amplifier, and an alloyed p-n-p junction (triode unit) for use as an audio amplifier. The two units are constructed on one germanium pellet so that the n-type base region is common to both units. This construction provides direct connection between the diode unit and the triode unit and thus permits the use of a minimum number of circuit components.

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Voltage Reference Packs

International Rectifier complete, miniaturized voltage reference packs capable of maintaining voltage regulation to within ±0.01% to replace standard cells or dry cell batteries in all equipment requiring stable voltage references. Especially suitable for providing stable voltage references in digital voltmeters, regulated power supplies, potentiometric recording equipment, fire control systems, autopilots, and similar applications. Withstand environmental and temperature extremes, and are operable to +125°C. Each unit completely encapsulated in standard miniature MIL-T-27 transformer case, with glass hermetic headers.

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Diffused Alloy Power Transistor

Bendix Diffused-Alloy-Power (DAP) transistor, combining higher frequency and greater circuit stability with greater power. Power gain is five to ten times greater than that of a standard alloy type, a result of lower input resistance. Also results in less distortion and better circuit stability at high temperatures. The new transistor fabrication process enables the unit to increase switching speed and frequency response three to five times faster than the standard alloy types, and it can be developed to handle 1200 watts in a switching application.

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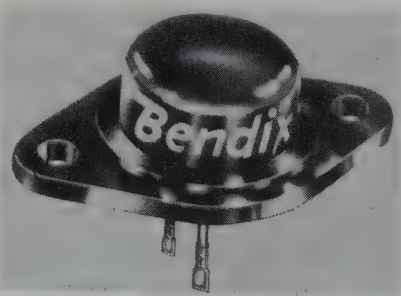
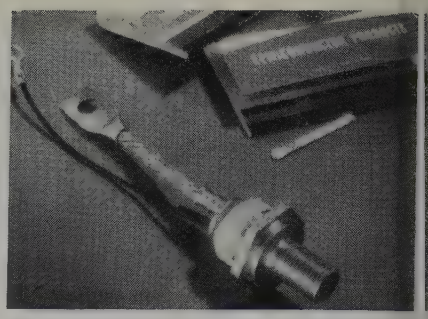


Silicon Controlled Rectifier

Atomic submarines, guided missiles, jet planes and TV theater lighting panels are expected to be among the first applications for General Electric's new high current silicon controlled rectifiers. Development samples available to equipment manufacturers prior to the start of commercial production later this year, have peak inverse voltage ratings of 25, 50, 75, 100, 150 and 200-volts. Capable of handling 50-amperes at 125°C. stud temperature in a single phase circuit. Typical gate current to fire the rectifiers is 15 ma at 1.5 volts. Typical turn-on time is 4-microseconds and turnloff time is 15-microseconds. The peak one-cycle surge current rating is 500-amperes.



Circle 112 on Reader Service Card

High Purity Metals

Consolidated Mining & Smelting Company displayed a variety of high purity metals, including indium, lead, tin, zinc, cadmium, bismuth, silver and antimony. These metals were shown in grades of 99.9999+% purity and contain less than one part per million total impurities. Shown are specimens of Tadanac Brand Special Research Grade indium, Tadanac Brand Special Research Grade antimony, and Tadanac Brand indium antimonide. The high purity indium is vacuum-sealed inside a fused quartz ampoule to protect it from contamination and it analyzes less than 0.1 parts per million of any single impurity of importance.

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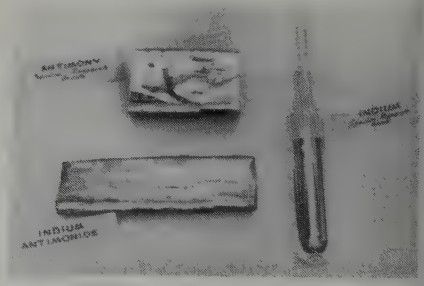

Ultra High Switching Transistor

The Motorola Mesa transistor type 2N-695 is a germanium P-N-P diffused junction transistor designed primarily for reliable operation in ultra high speed switching applications. Its structure provides the versatility required for dependable performance in a wide variety of computer pulse and switching circuits (both saturating and non-saturating). The internal design and hermetically sealed package enable it to meet or exceed the mechanical and environmental requirements of military specification MIL-T-19500A. The high maximum junction temperature of 100°C permits this Germanium transistor to be reliably operated in applications where Germanium transistors have not been previously considered.

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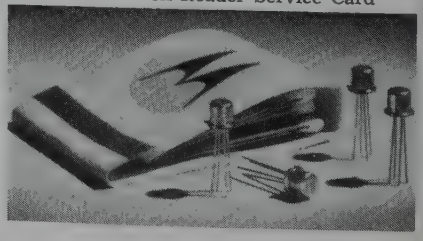
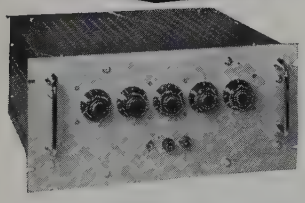


NORTH HILLS'



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For testing and measurement of diodes, transistors, rectifiers, thermistors, electrophoresis, other current sensitive devices.

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In use by leading companies for diode PIV test, diode life test, dynamic impedance test.

Literature describing this and other constant current sources from 0.1μa to 30 amp. may be obtained from

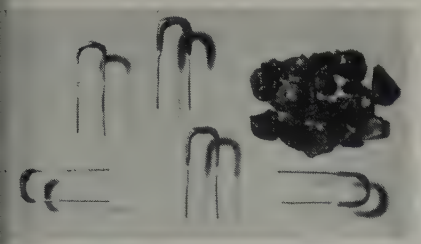
nh NORTH HILLS ELECTRIC COMPANY, INC
402 SAGAMORE AVE., MINEOLA, N.Y. Pioneer 7-0555

Circle No. 27 on Reader Service Card

Glass Coating

High-purity low-melting glass for coating electronic devices. Available from Baker & Adamson, General Chemical Div., Allied Chemical Corp. Ideal coating for protecting germanium and silicon transistors and diodes from atmospheric oxidation, contamination and humidity. Coating may be accomplished by dipping devices in a fluid bath of the glass, withdrawing and cooling; or through the use of a preform (compressed powder).

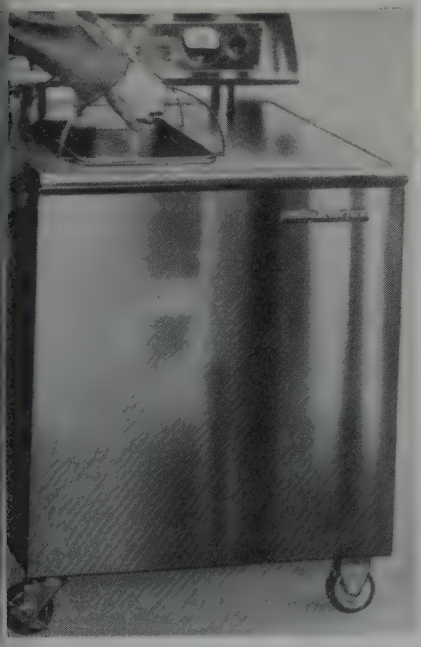
Circle No. 143 on Reader Service Card



Narda Ultrasonic Washing Machine

For cleaning and de-greasing small electronic and electromechanical parts. Model MC3000 Redstone Son Blaster has all stainless steel cabinet and plumbing. Uses solvents or tap water. Re-circulation system has pump, filter and thermostatically controlled 1 KW heater. Power drain and liquid level control. Ultrasonic cleaning compartment is 14" x 10" x 9". Operates on 117 volt 50/60 cycles; 11.0 amps. Generator output is 300 W average, 600 W peak, 40 KC.

Circle No. 144 on Reader Service Card



Transistor Test Instrument

Newest development in Baird-Atomic's test line, the MW-1 Curve Tracer is designed to display families of characteristic curves for PNP and NPN transistors in either common base or common emitter configurations. Input and/or output current or voltage may be selected as components of the curves displayed. Displays for either configuration are switch-selected and displays may be reversed or inverted. Draws maximum of 325 watts;

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Experienced in D&D or production engineering, transistors, silicon devices, crystal diodes or rectifiers.

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Coordinate electronic equipment projects — including development subcontracting, electrical design & procurement of parts for equipment for manufacture and testing of transistors & diodes. Some travel involved.

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Responsible for operation in final quality sampling department (commercial product), government inspection and customer return analysis & processing. BS/EE or Physics with heavy electronics background. Some semiconductor, other electronic component testing experience and supervisory experience desirable. Will consider less experienced recent graduate with good potential.

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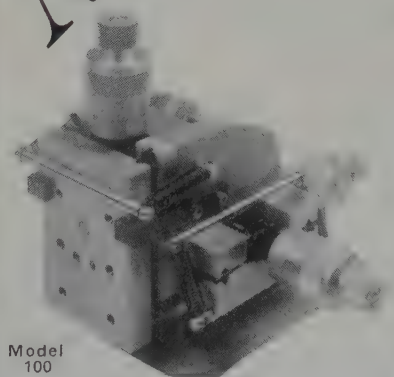

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half inch movement in three planes to tenths accuracy

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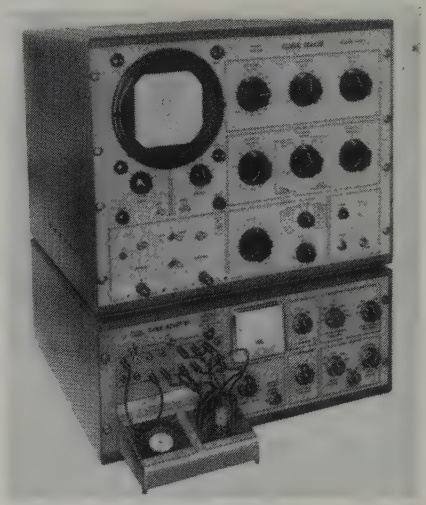

Voltage Regulating Diode

U. S. Semcor's Axial Lead Voltage Regulating Diode for use in computers measuring instruments and controls. Combines single diffused silicon junction advantages with newly developed triple wafer sandwiching method. Provides matched coefficients of expansion of lead wire and diode case, prohibits separation even under extreme shock. Results in .0005% per °C temperature coefficient over an operating range of —55°C to +185°C, .290" long x .250" O.D. package size. Rated at 9.0 to 9.8 volts at 10 millilamps, $Z_z = 15$ ohms. Non-position sensitive for most compact placement.

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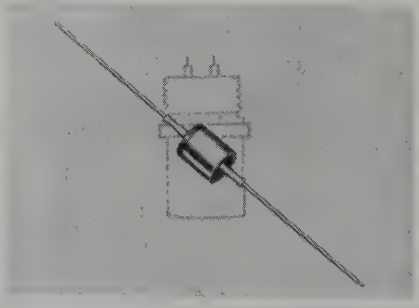

Diode Tester

Teletronics Laboratory Model DT-257 Diode Tester is a quality instrument for measuring the static characteristics of germanium, and low-power selenium, diodes. Separate forward and reverse power supplies have continuously variable outputs or pre-set regulated reverse potentials permit complete measurements or checks at selected operating points. The arrangement of controls and connectors and the circuits employed provide accurate results with a minimum of operations. Featuring: Pre-set Regulated Reverse Voltages, -10, -50, -100, 0-150 Volts at 5 ma., Forward Current to 500 ma. at 1.0 V., Reversed or Shorted Diode Indication, Internal Meter Overload Protection, Text Fixture Allows Buick Connection, Provision for Accessory Diode Heater. Shown rack-mounted with Model MA-259 Millimicroammeter.

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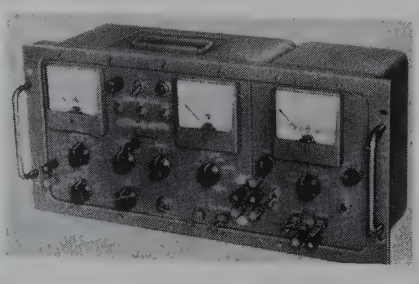

Silicon Power Rectifiers

Fansteel (1N Series) Silicon Rectifiers designed to provide a d-c source for all types of power applications requiring a high degree of reliability in ambient temperatures up to 165°C; are unaffected by storage temperatures from —65°C to 200°C. With exceptional shock and vibration resistance, they are hermetically sealed, can be mounted in any position and can be supplied with the stud as either the positive or negative terminal with or without flexible leads .

Circle 122 on Reader Service Card

High Power 4-Layer Diode

A higher power 4-layer diode designated as Type AD exhibited by the Shockley Transistor Corporation. This self-actuated silicon switch is turned on by a voltage pulse, turned off by dropping the current or reversing the voltage. To match circuit requirements, it is available with switching voltages of 30, 40, and 50 and 200 volts and holding currents of 5 to 45 ma. Capable of handling 300 ma steady d.c. or 20-ampere pulse current. A string of four in series will switch 800 volts, resulting in peak power of 16kw, allowing use in magnetron pulsing, radar beacons and other modulator applications.

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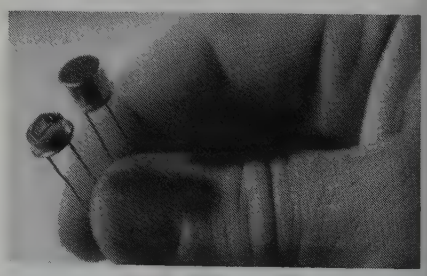
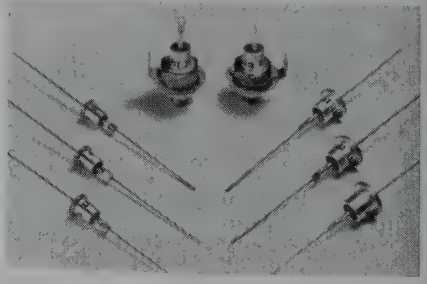


Silicon Zener Regulator Diodes

Exhibited by the ITT Components Division of International Telephone and Telegraph Corporation. Available in four nominal basic power ratings: Series B,



750 milliwatts; Series T, 1 watt; Series G, 3.5 watts; and Series K, 10 watts; the first two in an axial pigtail top hat package and the higher power devices in 10-32 stud-mounted cases. Zener breakdown voltage ranges cover from 3.6 volts to 30 volts in each power rating, making the devices suitable for wide use in the design of automatic machinery, aircraft and missiles, computers, communication equipment and many other kinds of industrial and military equipment.

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Tektronix Oscilloscope

Type 581 is a general-purpose oscilloscope with excellent transient response and high-speed sweeps. Risetime is 3.5 mμsec and sweep time is calibrated to 0.01 μsec/mc. Passband is dc to approximately 100 mc. The vertical deflection system is designed for plug-in preamplifiers. A low-capacitance probe is an integral part of the Type 80 Plug-In Preamplifier, which provides a calibrated deflection factor of 0.1 v/cm. Sufficient signal delay is included in the main vertical amplifier to permit displaying the leading edge of the wave-form under observation.

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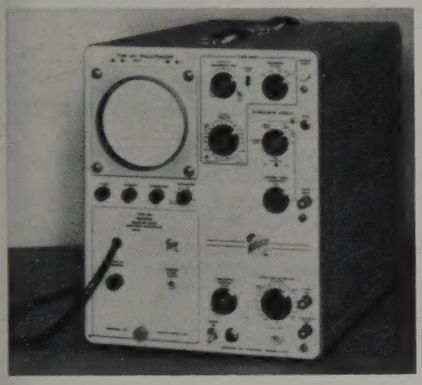

Special Vacuum Equipment

Specially designed equipment for outgassing and sealing of semiconductor components under vacuum demonstrated by F. J. Stokes Corp. Also exhibited series of small compound high vacuum pumps, in the 2 to 3 cfm. range, which are suitable for a number of electronic manufacturing and testing operations, such as small vacuum-impregnation systems for capacitors, transformers, and the like; small vacuum-metallizing units; and evacuating environmental testing chambers.

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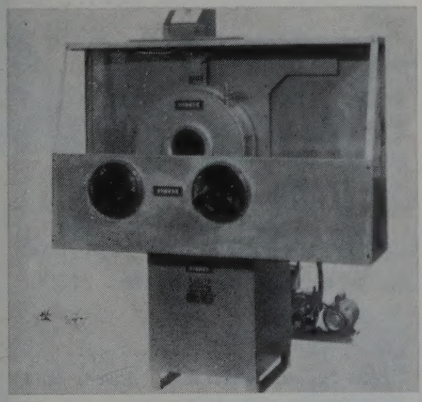

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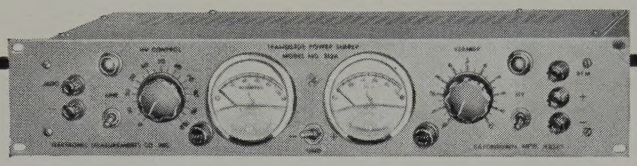
1 *REGATRON POWER SUPPLY DOES THE WORK OF 3 ORDINARY POWER SUPPLIES

a case history



(Model 212AM:
0-100 V dc, 0-100 ma,
$129.00 unmetered)

A MANUFACTURER required three different regulated voltages. The voltages, which were to be used alternately, could be furnished by three separate power supplies or by a single power supply and a voltage divider. But, three power supplies were expensive. On the other hand, a voltage divider meant a loss of power and regulation plus the expense of high-wattage components.

THE SOLUTION: Three 1-watt resistors and a *Regatron Programmable Power Supply. An exclusive programming feature permits changing output voltage by shunting two terminals with a resistor. For each 1000 ohms, the Regatron delivers one volt . . . at rated current and regulation.

IN THE PROBLEM quoted here, the required voltages were 14.5, 28, and 45 V dc. The three resistors were 14.5K, 28K, and 45K. Regatron Programmable Power Supplies are available in many ranges up to 600 V dc and 3 amperes. Bulletin 765A tells more about how Programmable Regatrons solve d-c problems. Write for your copy.

POWER FACT No. 6 Ripple and Noise:

Ripple and noise, in some degree, are inherent in all power supplies. The relative importance of given types and magnitudes is closely linked to the application. Surprisingly, external factors may contribute.

For definitions and a useful discussion of these matters, send for Technical Bulletin No. 2006. It is free of charge.

*Registered U.S. Patent Office. U.S. Patents Issued and Pending.

E/M ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN • NEW JERSEY

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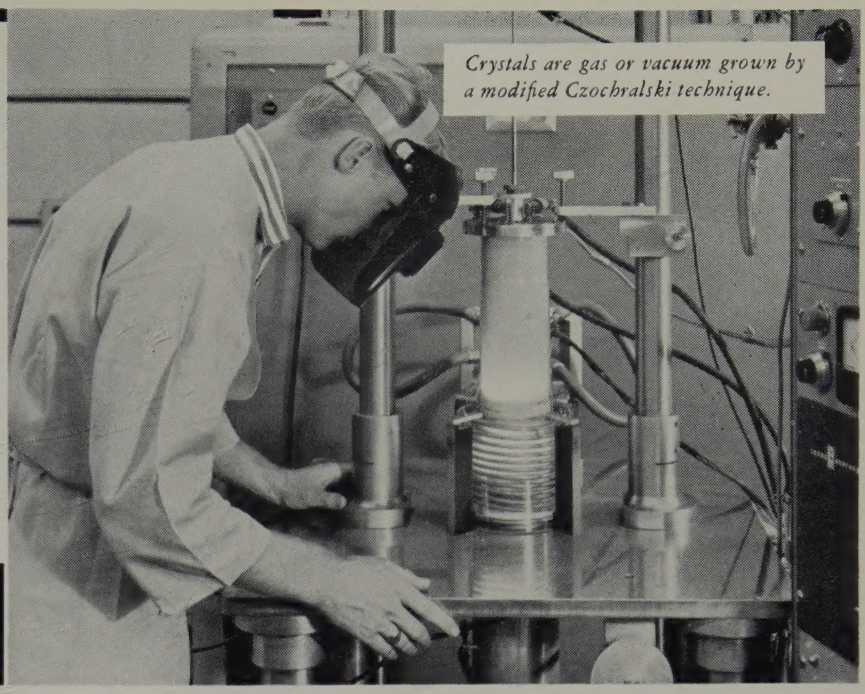


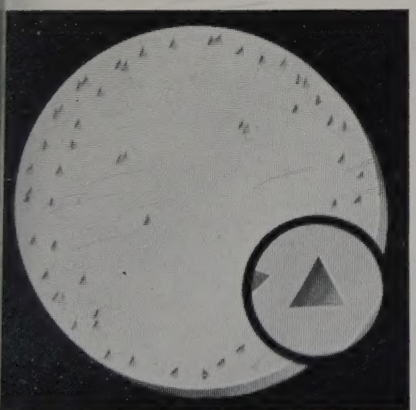
Crystals are gas or vacuum grown by a modified Czochralski technique.

SILICON AND GERMANIUM MONOCRYSTALS

For Semiconductor, Solar Cell and Infrared Devices

Major manufacturers of semiconductor devices have found that Knapic Electro-Physics, Inc. can provide production quantities of highest quality silicon and germanium monocrystals far quicker, more economically, and to much tighter specifications than they can produce themselves. Knapic Electro-Physics has specialized in the custom growing of silicon and germanium monocrystals. We have extensive experience in the growing of new materials to specification. Why not let us grow your crystals too?

Knapic monocrystalline silicon and germanium is available in evaluation and production quantities in all five of the following general grade categories –Zener, solar cell, transistor, diode and rectifier, and high voltage rectifier.



Dislocation density, Knapic silicon monocrystals. Crystal diameter 1/10" to 3/8"—None; 3/8" to 3/4"—less than 10 per sq. cm.; 3/4" to 1-1/4"—less than 100 per sq. cm.; 1-1/2" to 2" less than 1000 per sq. cm.

SPECIFICATIONS – Check These Advantages

- ☐ **Extremely** low dislocation densities.
- ☐ **Tight** horizontal and vertical resistivity tolerances. Resistivities available in controlled ranges .005 to 1000 ohm cm., N and P type.
- ☐ **Diameters** from .10" to 2". Wt. to 250 grams per crystal. Individual crystal lengths to 10".
- ☐ **Low Oxygen content** 1×10^{17} per cc., 1×10^{16} for special Knapic small diameter material.
- ☐ **Doping** subject to customer specification, usually boron for P type, phosphorus for N type.
- ☐ **Lifetimes:** 1 to 15 ohm cm.—over 50 microseconds; 15 to 100 ohm cm.—over 100 microseconds; 100 to 1000 ohm cm.—over 300 microseconds. Special Knapic small diameter material over 1000 microseconds.

Specification Sheets Available

Infrared Domes and Lenses

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Individual silicon ingots for lens use to 10" diameter and hollow grown domes to 8" diameter are now available in production and evaluation quantities. Diameters up to 19" will be available in the near future. Transmission characteristics—minimum 52%, coated 97% in ranges between 1 to 15 microns.

Quotations will be prepared on request for production orders, for semiconductor materials not falling within the listed categories, or for those requiring additional experimental work.

Knapic Electro-Physics, Inc.

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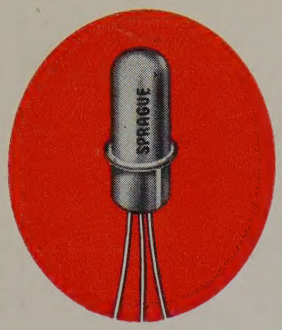
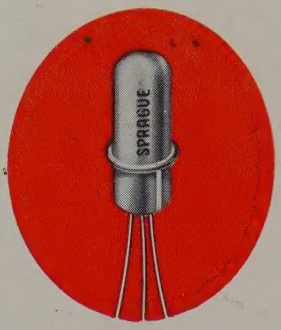


2N393



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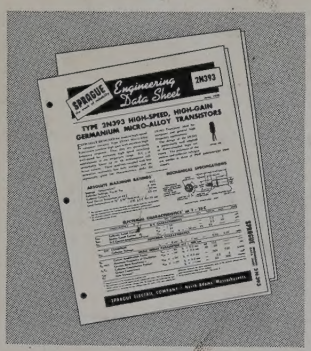
2N1122

HIGH-SPEED, HIGH-GAIN MICRO-ALLOY TRANSISTORS for modern computer circuitry

Types 2N393 and 2N1122 Micro-Alloy Transistors combine high gain with excellent high frequency response to meet demands of high-speed computer switching applications in the megacycle range. Low saturation resistance, low hole storage, and exceptionally good life characteristics make these micro-alloy transistors top performers in general high frequency applications and computer circuits.



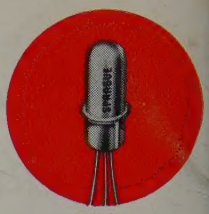
Made by electrochemical manufacturing techniques, Sprague Micro-Alloy Transistors are uniformly reliable, as well as reasonably priced for transistors with such excellent operating parameters.

All Sprague transistors—micro-alloy, micro-alloy diffused base, and surface barrier types—are now produced in Sprague's completely new spotless semiconductor facility.

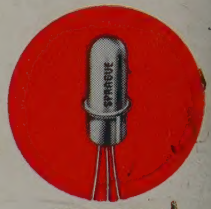
For engineering data sheets on the types in which you are interested, write Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

Sprague micro-alloy, micro-alloy diffused base, and surface barrier transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type numbers are manufactured to the same specifications and are fully interchangeable. You have two sources of supply when you use micro-alloy and surface barrier transistors!

Other popular SPRAGUE transistors



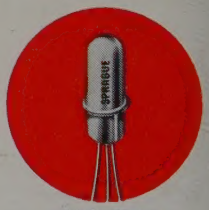
2N128
SB MIL GENERAL PURPOSE
(MIL-T-12679A)



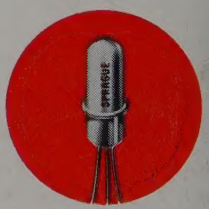
2N240/SB5122
FOR COMPUTER SWITCHING

2N344/SB101
FOR MEDIUM GAIN AMPLIFIERS

2N345/SB102
FOR HIGH GAIN AMPLIFIERS



2N246/SB103
FOR HIGH FREQUENCY OSCILLATORS



2N501
MADT FOR ULTRA-HIGH SPEED SWITCHING

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